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SITE-SPECIFIC TECHNICAL REPORT FOR FREE PRODUCT RECOVERY TESTING AT SITES 27 AND 28 NELLIS AFB, NEVADA

DRAFT

PREPARED FOR:

AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE
TECHNOLOGY TRANSFER DIVISION
(AFCEE/ERT)
8001 ARNOLD DRIVE
BROOKS AFB, TEXAS 78235-5357

AND

NELLIS AFB, NEVADA

6 NOVEMBER 1997

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SITE-SPECIFIC TECHNICAL REPORT (A003)

for

FREE PRODUCT RECOVERY TESTING AT SITES 27 & 28, NELLIS AFB, NEVADA

by

J. Kramer, A. Leeson, G. Headington, S. Walton, and J. Eastep

for

Mr. Patrick Haas
U. S. Air Force Center for Environmental Excellence
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(AFCEE/ERT)
Brooks AFB, Texas 78235

6 November 1997

Battelle
505 King Avenue
Columbus, Ohio 43201-2693

Contract No. F41624-94-C-8012

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ABBREVIATIONS AND ACRONYMS

AFB	Air Force Base
AFCEE	U.S. Air Force Center for Environmental Excellence
AGT	aboveground tank
BTEX	benzene, toluene, ethylbenzene, and xylenes
LNAPL	light, nonaqueous-phase liquid
MP	monitoring point
MW	monitoring well
POL	petroleum, oil, and lubricants
PVC	polyvinyl chloride
SVE	soil vapor extraction
TPH	total petroleum hydrocarbons
UST	underground storage tank

EXECUTIVE SUMMARY

This report summarizes the field activities conducted at Nellis Air Force Base (AFB), for a short-term field pilot test to compare vacuum-enhanced free-product recovery (bioslurping) to traditional free-product recovery techniques to remove light, nonaqueous-phase liquid (LNAPL) from subsurface soils and aquifers. The field testing at Nellis AFB is part of the Bioslurper Initiative, which is funded and managed by the U.S. Air Force Center for Environmental Excellence (AFCEE) Technology Transfer Division. The AFCEE Bioslurper Initiative is a multisite program designed to evaluate the efficacy of the bioslurping technology for (1) recovery of LNAPL from groundwater and the capillary fringe, and (2) enhancing natural in situ degradation of petroleum contaminants in the vadose zone via bioventing.

The main objective of the Bioslurper Initiative is to develop procedures for evaluating the potential for recovering free-phase LNAPL present at petroleum-contaminated sites. The overall study is designed to evaluate bioslurping and identify site parameters that are reliable predictors of bioslurping performance. To measure LNAPL recovery in a wide variety of in situ conditions, tests are being performed at many sites. The tests at Nellis AFB are two of over 40 similar field tests to be conducted at various locations throughout the United States and its possessions.

The intent of field testing is to collect data to support determination of the predictability of LNAPL recovery and to evaluate the applicability, cost, and performance of the bioslurping technology for removal of free product and remediation of the contaminated area. The on-site testing is structured to allow direct comparison of the LNAPL recovery achieved by bioslurping with the performance of more conventional LNAPL recovery technologies. The test method included an initial site characterization followed by LNAPL recovery testing. The three LNAPL recovery technologies tested at Nellis AFB were skimmer pumping, bioslurping, and drawdown pumping. The bioslurper pilot test activities were carried out at both Sites 27 and 28 at Nellis AFB

Site characterization activities were conducted to evaluate site variables that could affect LNAPL recovery efficiency and to determine the bioventing potential of the site. Testing included baildown testing to evaluate the mobility of LNAPL and in situ respiration testing to evaluate site microbial activity. Site characterization activities were limited by the great depth to the groundwater table, for which reason soil gas monitoring points were not installed.

Site 27

Following the site characterization activities, the pump tests were conducted. Pilot tests for skimmer pumping, bioslurping, and drawdown pumping were conducted at monitoring well MW-24. In addition, soil vapor extraction (SVE) was conducted briefly at MW-24, however was discontinued immediately. The LNAPL recovery testing was conducted in the following sequence: 41.5 hours in the skimmer configuration, 96 hours in the bioslurper configuration, approximately 4 hours in the SVE configuration, and 41 hours in the drawdown configuration.

A baildown recovery test was conducted at monitoring well MW-24. Baildown recovery tests provide a qualitative indication of the presence of mobile, free-phase LNAPL and recovery potential. The baildown recovery test at MW-24 indicated a relatively quick rate of LNAPL recovery into the well and resulted in an LNAPL thickness nearly equal to the initial apparent thickness. Site logistics limited the number of wells which could potentially be used for bioslurper pilot testing at each of the sites; therefore, baildown testing was limited to monitoring well MW-24.

None of the LNAPL recovery techniques were successful at recovering free product from MW-24 at Site 27. Less than 1 gallon of fuel each was recovered during the skimmer and the bioslurper pump tests, and no fuel was recovered during the drawdown pump testing. A fuel-only recovery pump was used for the skimmer pump test; therefore, groundwater was not recovered. The groundwater was extracted at a relatively constant recovery rate throughout the bioslurper and drawdown pump tests, with respective rates of 2,100 gallons/day and 2,000 gallons/day.

Bioslurping also promotes mass removal in the form of in situ biodegradation via bioventing and soil gas extraction. Vapor phase mass removal is the result of soil gas extraction as well as volatilization that occurs during the movement of LNAPL free product through the extraction network. Given the measured vapor flowrate (6.7 scfm) and average vapor concentrations at MW-24, initial hydrocarbon removal rates were approximately 57 lb/day of TPH and 0.047 lb/day of benzene.

The initial soil gas profiles at the site displayed relatively oxygen-deficient vapor conditions with high volatile hydrocarbons at all depths of the existing monitoring points. These conditions indicate that natural biodegradation of residual petroleum hydrocarbons has occurred, but is limited by oxygen availability. Soil gas monitoring points were located too far away to determine if the vadose zone was being oxygenated via the bioslurper action. In situ biodegradation rates of 0.41 to 2.6 mg/kg-day were measured at three different locations of the monitoring points. Based on an estimated radius of influence of 70 ft and a hydrocarbon-impacted soil thickness of 70 ft, mass removal rates via biodegradation are on the order of 12 to 78 lbs of hydrocarbon per day. Thus,

mass removal rates via biodegradation could be as significant as the initial vapor phase removal rates measured during the bioslurper test. These results indicate that bioventing is feasible at this site. Air injection bioventing is preferable over bioslurping and soil vapor extraction with respect to the elimination of hydrocarbon vapor emissions.

Based on pilot test results from MW-24, implementation of bioslurping or any free-product recovery technique does not appear to facilitate LNAPL recovery. The most appropriate technology for this site may be bioventing to treat significant vadose zone contamination, coupled with periodic baildown of monitoring wells should free product appear.

Site 28

Following the site characterization activities, the pump tests were conducted. Pilot tests for skimmer pumping, bioslurping, and drawdown pumping were conducted at monitoring well MW-31. Pilot tests for skimmer pumping, bioslurping, and drawdown pumping were conducted at monitoring well MW-31. The LNAPL recovery testing was conducted in the following sequence: 41.5 hours in the skimmer configuration, approximately 95 hours in the bioslurper configuration, and approximately 26 hours in the drawdown configuration. Measurements of extracted soil gas composition, LNAPL thickness, and groundwater level were taken throughout the testing. The volume of LNAPL recovered and groundwater extracted were quantified over time.

A baildown recovery test was conducted at monitoring well MW-31. Baildown recovery tests provide a qualitative indication of the presence of mobile, free-phase LNAPL and recovery potential. The baildown recovery test at MW-31 indicated a relatively slow rate of LNAPL recovery and resulted in an LNAPL thickness substantially less than the initial apparent thickness. Site logistics limited the number of wells which could potentially be used for bioslurper pilot testing at each of the sites, therefore baildown testing was limited to monitoring well MW-31.

None of the LNAPL recovery techniques were successful at recovering free product from MW-31 at Site 28. Less than 1 gallon of fuel was recovered throughout the entire sequence of pump tests. A fuel-only recovery pump also was used for the skimmer pump test at MW-31, therefore groundwater was not recovered during this recovery test. The groundwater was extracted at a relatively constant recovery rate throughout the bioslurper and drawdown pump tests, with respective rates of 840 gallons/day and 830 gallons/day.

Bioslurping also promotes mass removal in the form of in situ biodegradation via bioventing and soil gas extraction. Vapor phase mass removal is the result of soil gas extraction as well as

volatilization that occurs during the movement of LNAPL free product through the extraction network. Given the measured vapor flowrate (9.5 scfm) and average vapor concentrations at MW-31, initial hydrocarbon removal rates were approximately 320 lb/day of TPH and 0.49 lb/day of benzene.

Based on pilot test results from MW-31, implementation of bioslurping or any free-product recovery technique does not appear to facilitate LNAPL recovery. Although an in situ respiration test could not be conducted, based on off-gas concentrations, it is possible that bioventing would be effective at remediating the vadose zone soils. Periodic baildown of monitoring wells may be the most effective means for handling the periodic appearance of free product.

DRAFT SITE-SPECIFIC TECHNICAL REPORT (A003)

for

FREE PRODUCT RECOVERY TESTING
AT SITES 27 & 28, NELLIS AFB, NEVADA

6 November 1997

1.0 INTRODUCTION

This report describes activities performed and data collected during field tests at Nellis Air Force Base (AFB), Nevada to compare vacuum-enhanced free-product recovery (bioslurping) to traditional free-product recovery technologies for removal of light, nonaqueous-phase liquid (LNAPL) from subsurface soils and aquifers. The field testing at Nellis AFB is part of the Bioslurper Initiative, which is funded and managed by the U.S. Air Force Center for Environmental Excellence (AFCEE) Technology Transfer Division. The AFCEE Bioslurper Initiative is a multisite program designed to evaluate the efficacy of the bioslurping technology for (1) recovery of LNAPL from groundwater and the capillary fringe and (2) enhancing natural in situ degradation of petroleum contaminants in the vadose zone via bioventing.

1.1 Objectives

The main objective of the Bioslurper Initiative is to develop procedures for evaluating the potential for recovering free-phase LNAPL present at petroleum-contaminated sites. The overall study is designed to evaluate bioslurping and identify site parameters that are reliable predictors of bioslurping performance. To measure LNAPL recovery in a wide variety of in situ conditions, tests are being performed at many sites. The tests at Nellis AFB are two of over 40 similar field tests to be conducted at various locations throughout the United States and its possessions. Aspects of the testing program that apply to all sites are described in the Test Plan and Technical Protocol for Bioslurping (Battelle, 1995). Test provisions specific to activities at Nellis AFB were described in the Site-Specific Test Plan provided in Appendix A.

The intent of field testing is to collect data to support determination of the predictability of LNAPL recovery and to evaluate the applicability, cost, and performance of the bioslurping technology for removal of free product and remediation of the contaminated area. The on-site testing is structured to allow direct comparison of the LNAPL recovery achieved by bioslurping with the performance of more conventional LNAPL recovery technologies. The test method included an initial site characterization followed by LNAPL recovery testing. The three LNAPL recovery technologies tested at Nellis AFB were skimmer pumping, bioslurping, and drawdown pumping. In addition, a soil vapor extraction (SVE) test was conducted. The specific test objectives, methods, and results for the Nellis AFB test program are discussed in the following sections.

1.2 Testing Approach

Site characterization activities were conducted to evaluate site variables that could affect LNAPL recovery efficiency and to determine the bioventing potential of the site. Testing included baildown testing to evaluate the mobility of LNAPL, soil sampling to determine physical/chemical site characteristics, soil gas permeability testing to determine the radius of influence, and in situ respiration testing to evaluate site microbial activity.

Following the site characterization activities, the pump tests were conducted. Pilot tests for skimmer pumping, bioslurping, SVE, and drawdown pumping were conducted at monitoring well MW-24 at Site 27. The LNAPL recovery testing was conducted in the following sequence: 41.5 hours in the skimmer configuration, 96 hours in the bioslurper configuration, approximately 4 hours in the SVE configuration, and 41 hours in the drawdown configuration.

At Site 28, pilot tests for skimmer pumping, bioslurping, and drawdown pumping were conducted at monitoring well MW-31. The LNAPL recovery testing was conducted in the following sequence: 41.5 hours in the skimmer configuration, approximately 95 hours in the bioslurper configuration, and approximately 26 hours in the drawdown configuration. Measurements of extracted soil gas composition, LNAPL thickness, and groundwater level were taken throughout the testing. The volume of LNAPL recovered and groundwater extracted were quantified over time.

2.0 SITE DESCRIPTION

The following site description is based on documents prepared for the U.S. Army Corps of Engineers, Omaha District by Montgomery Watson. The documents present data obtained as part of remedial investigations at Sites 27 and 28, Nellis AFB, Nevada. The documents are titled *Installation Restoration Program Site 27 Remedial Investigation and Interim Remedial Action/Pilot Study for Site 28, Work Plan for the Pilot Extraction System.*

The geology of the area is characterized by a fine-grained sediment matrix of silt and clay. The matrix is interbedded with discontinuous silt- and clay-rich lenses with caliche horizons. The individual layers may be up to 5 feet thick. The fine-grained matrix consists of 0 to 30% very fine-grained sand and 70 to 100% fine silts and clays. The silt- and clay-rich sand appears as discontinuous lenses within the fine-grained matrix of the silt and silty clay. The caliche was found in the form of nodules within the matrix of silt and clay, as dense well-cemented semicontinuous layers, and as thinly-bedded horizons interlayed with the silts and clays.

Groundwater flow in the vicinity of Sites 27 and 28 is to the east and southeast. Depth to groundwater varies greatly throughout the base. In the central portion of the base (Area I), depth to groundwater is approximately 65 to 80 feet bgs. In Area II, depths are in the general range of 140 to 160 feet bgs. Groundwater depths increase to 250 to 300 feet bgs toward the northern end of the base which is situated on top of a thick sequence of alluvial fan sediments. Groundwater data collected since 1988 indicate a general rise in the groundwater table. Water levels in monitoring wells, located on the western portion of Site 27, increased 1.2 feet/yr between 1988 and 1993. The cause of the rise of the shallow water table aquifer has been attributed to reduced use of on-base production wells.

2.1 Contamination at Site 27

Figure 1 is a site map depicting the various monitoring well, soil boring, and product recovery well locations at Site 27. The area designated as Site 27 was originally the location of an underground storage tank (UST) at Facility 1014. Facility 1014 contained four 20,000 gallon concrete storage tanks originally used to store heating oil and later converted to waste petroleum, oil, and lubricants (POL) storage in 1974. It has been estimated that approximately 50 gallons per month of waste POL and solvents leaked from the southern-most of the four tanks. Leakage was discovered

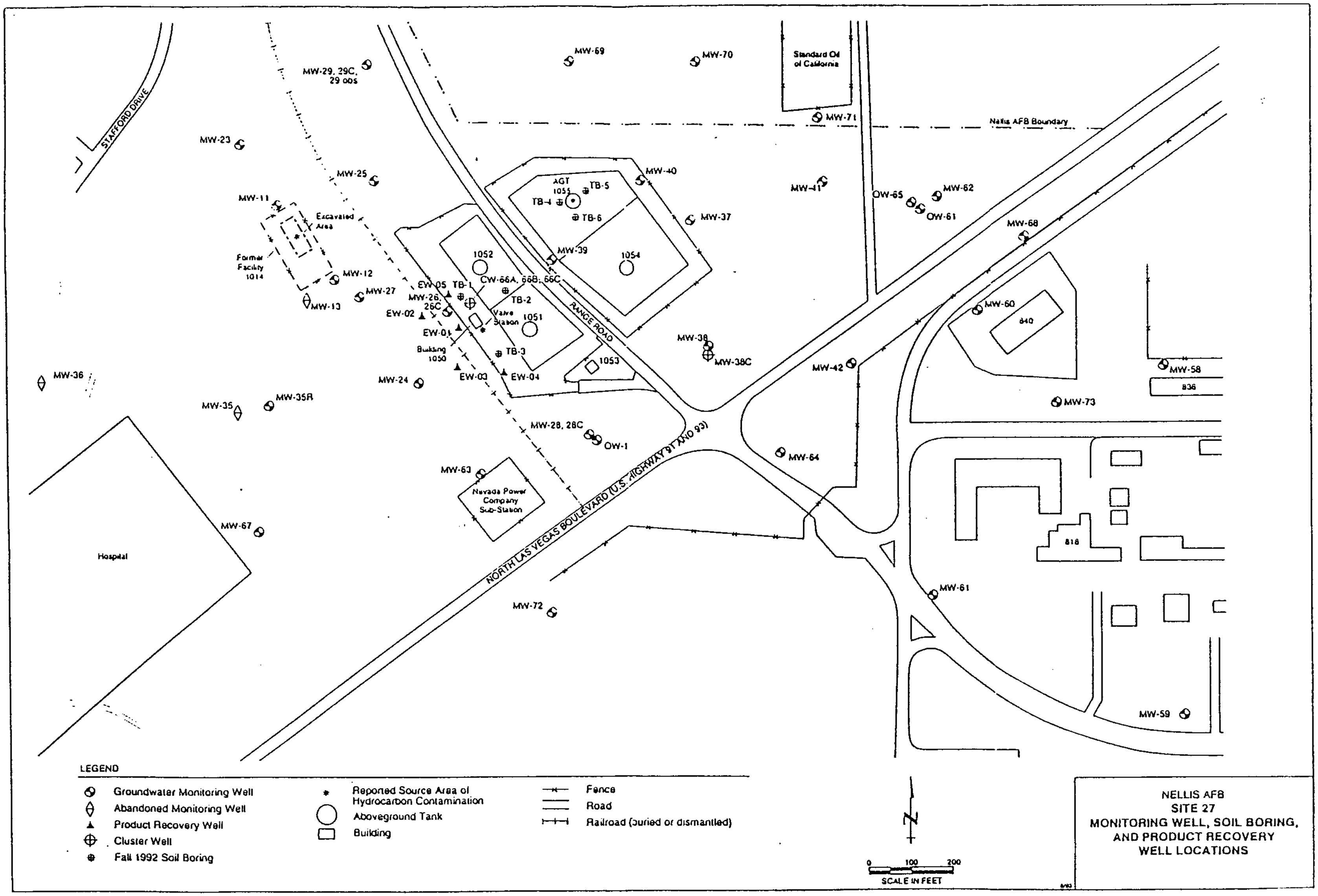

Figure 1. Monitoring Well, Soil Boring, and Product Recovery Well Locations at Site 27, Nellis AFB, NV

in 1981 and had been occurring for an unknown amount of time, possibly a number of years. Other hazardous wastes were also stored in drums within the fenced-in area at Facility 1014. The site was officially closed in April 1988 by discontinuing use of the storage tanks. The underground tanks, drums, and fencing were removed from the site and Facility 1014 no longer exists.

Since the removal of the tanks, two additional sources of contamination were discovered. Both sources were leaks associated with an aboveground tank (AGT) farm east of Facility 1014. There are four existing AGTs (Facility Nos.1051, 1052, 1054, and 1055) at the farm containing JP-4 jet fuel (Figure 1). The AGTs at Facilities 1051 and 1052 each have a 10,000 barrel capacity. The AGTs at Facilities 1054 and 1055 have 20,000 and 15,000 barrel capacities, respectively. One of the reported leakages was associated with the aboveground valve system in the tank farm area, and the other was an underground leak at AST 1054. The leaks were repaired in the spring and summer of 1992. This leakage appears to have been the primary source of free-phase product plume beneath Site 27. Data indicate that several monitoring wells at Site 27 have shown considerable product thickness values during measurements made from 1988 to 1993, with a maximum thickness of nearly 11 ft being measured in MW-26.

2.2 Contamination at Site 28

Figure 2 is a site map depicting the various monitoring wells and associated free product thicknesses reported for December 1992 at Site 28. Free product was present in several monitoring wells with a maximum thickness of 6.31 ft detected in monitoring well MW-33.The contamination at Site 28 has been characterized as JP-4 jet fuel, which leaked into the subsurface from USTs and associated piping at Fuel Facility 941. Site 28 is located just south of Building 941, near the northeast end of the flight line, and is surrounded by a masonry wall. Two 2,000-gallon JP-4 spills were reported in this area between 1967 and 1982. Each spill was contained within the unlined dike area and allowed to evaporate into the air and percolate into the soil. The result of this leakage was an extensive LNAPL plume, associated soil contamination, and a dissolved-phase contaminated groundwater plume.

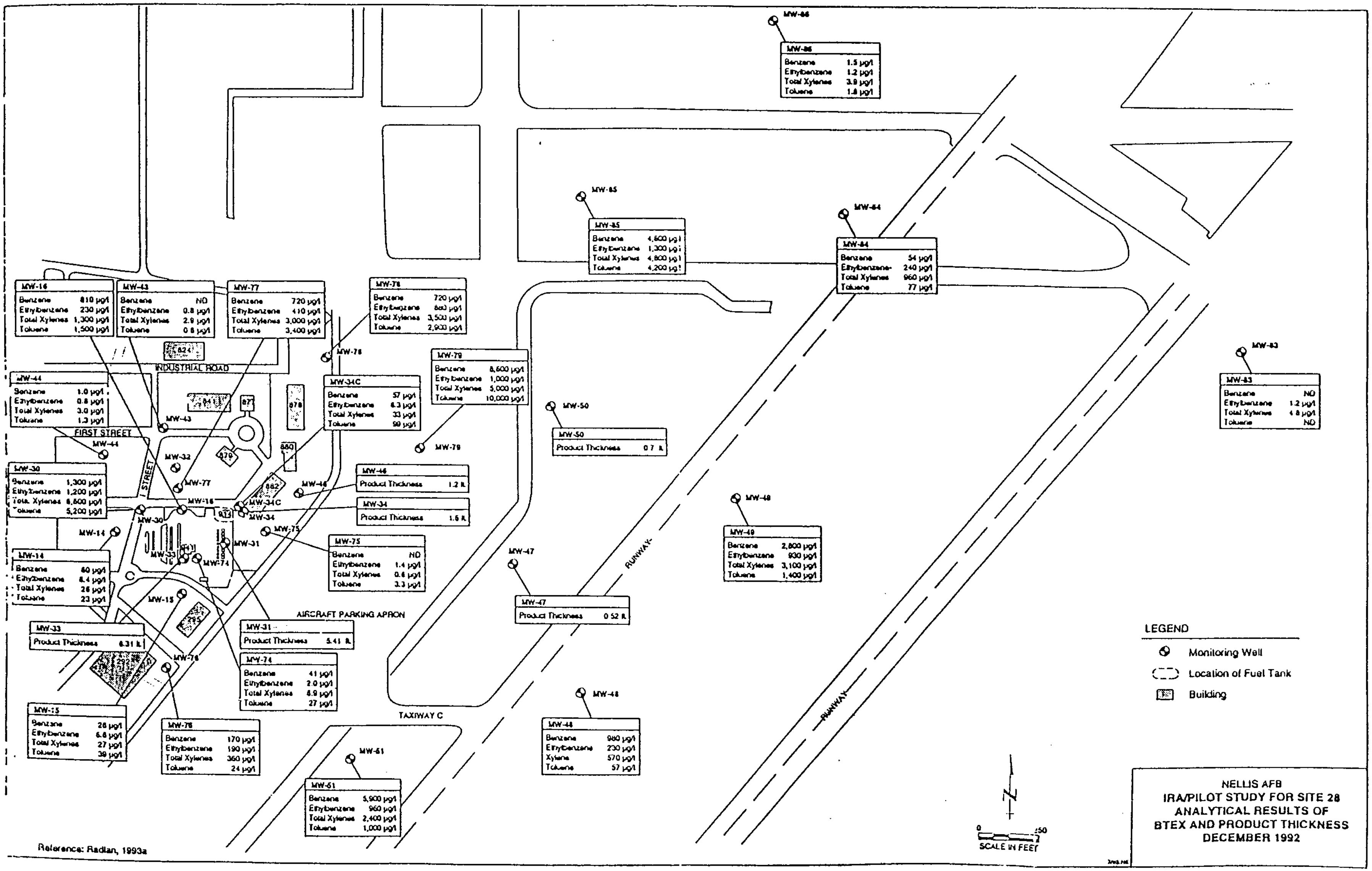

Figure 2. Monitoring Well Locations and Free-Product Thicknesses at Site 28, Nellis AFB, NV

3.0 FREE PRODUCT RECOVERY TESTING AT SITE 27

3.1 Pilot Test Methods

This section documents the initial conditions at the test site and describes the test equipment and methods used for the short-term pilot test at Site 27, Nellis AFB. A soil gas permeability test was not conducted because the soil gas monitoring points were located too far from the extraction well to detect pressure changes.

3.1.1 Initial LNAPL/Groundwater Measurements and Baildown Testing

Monitoring well MW-24 was evaluated for use in the bioslurper pilot testing. Initial depths to LNAPL and to groundwater were measured using an oil/water interface probe (ORS Model #1068013). LNAPL was removed from the well with a Teflon® bailer until the LNAPL thickness could no longer be reduced. The rate of increase in the thickness of the floating LNAPL layer was monitored using the oil/water interface probe for approximately 5 hours.

3.1.2 Well Construction Details

A short-term bioslurper pump test was conducted at existing monitoring well MW-24 at Site 27. The well is constructed of 2-inch-diameter, schedule 40 polyvinyl chloride (PVC). The monitoring well was constructed to a total depth of 100 ft and screened from 70 to 100 ft bgs.

3.1.3 Soil Gas Monitoring Points

Three existing monitoring points located approximately 100 yards from MW-24 were utilized to conduct treatability testing at Site 27. The monitoring points, labeled MPA, MPB, and MPC, each have screened intervals positioned at depths of 55, 65, and 70 ft.

Initial soil gas measurements were taken at each of the monitoring points with a GasTechtor portable O_2/CO_2 meter and a GasTech Trace-Techtor portable hydrocarbon meter. Oxygen levels were significantly depressed at all monitoring point depths with correspondingly high total petroleum hydrocarbon (TPH) concentrations (Table 1).

Table 1. Initial Soil Gas Compositions at Site 27

Monitoring Point	Depth (ft)	Oxygen (%)	Carbon Dioxide (%)	TPH (ppmv)
MPA	55	0.0	0.50	>100,000
	65	0.0	25	>100,000
	70	0.80	0.70	56,000
MPB	55	0.0	2.8	47,000
	65	NA	NA	NA
	70	0.0	0.70	>100,000
MPC	55	0.0	0.70	>100,000
	65	NA	NA	NA
	70	0.0	0.60	>100,000

NA = Not applicable. Monitoring point was plugged.

3.1.4 LNAPL Recovery Testing

3.1.4.1 System Setup

The bioslurping pilot test system is a trailer-mounted mobile unit. The vacuum pump (Atlantic Fluidics Model A100, 10-hp liquid ring pump), oil/water separator, and required support equipment were transported to the test location on a trailer. The trailer was located near monitoring well MW-24, the well cap was removed, a coupling and tee were attached to the top of the well, and the drop tube was lowered into the well. The drop tube was attached to the vacuum pump. Different configurations of the tee and the placement depth of the slurper tube allow for simulation of skimmer pumping, operation in the bioslurping configuration, or simulation of drawdown pumping. Extracted groundwater was treated by passing the effluent through a filter box, an oil/water separator, a 325 gallon tank, and then pumped to the OHM oil/water separator existing at the site for other remedial activities. Extracted soil gas was discharged directly to the atmosphere.

A brief system startup test was performed prior to LNAPL recovery testing to ensure that all system components were working properly. The system checklist is provided in Appendix C. All site data and field testing information were recorded in a field notebook and then transcribed onto pilot test data sheets provided in Appendix D.

3.1.4.2 Skimmer Pump Test

Prior to test initiation, depths to LNAPL and groundwater were measured. A Ferret® downhole skimming pump was used to conduct the skimmer pump test. The Ferret® pump is a free product only recovery pump, therefore groundwater was not extracted. The Ferret® pump inlet was placed at a depth of 69.8 ft, and the pump was started at 1600, 10 August 1997 to begin the skimmer pump test. The test was operated continuously for 41.5 hours. The LNAPL extraction rate was monitored throughout the test, as were all other relevant data for the skimmer pump test. Test data sheets are provided in Appendix D.

3.1.4.3 Bioslurper Pump Test

Prior to test initiation, depths to LNAPL and groundwater were measured. The slurper tube was then set at the LNAPL/groundwater interface at a depth of 71.2 ft. The PVC connecting tee was removed, sealing the wellhead and allowing the pump to establish a vacuum in the well (Figure 3). A pressure gauge was installed at the wellhead to measure the vacuum inside the extraction well. The liquid ring pump and oil/water separator were primed with known amounts of groundwater to ensure that any LNAPL or groundwater entering the system could be quantified. The flow totalizers for the LNAPL and aqueous effluent were zeroed, and the liquid ring pump was started at 1100, 12 August 1997 to begin the bioslurper pump test. The test was initiated approximately 2.5 hours after the skimmer pump test and was operated continuously for 96 hours. The pump head vacuum was approximately 24 inches Hg and the well head vacuum was approximately 50 inches H_2O. The temperature-corrected vapor flowrate was approximately 6.7 scfm. The LNAPL and groundwater extraction rates were monitored throughout the test, as were all other relevant data for the bioslurper pump test. Test data sheets are provided in Appendix D.

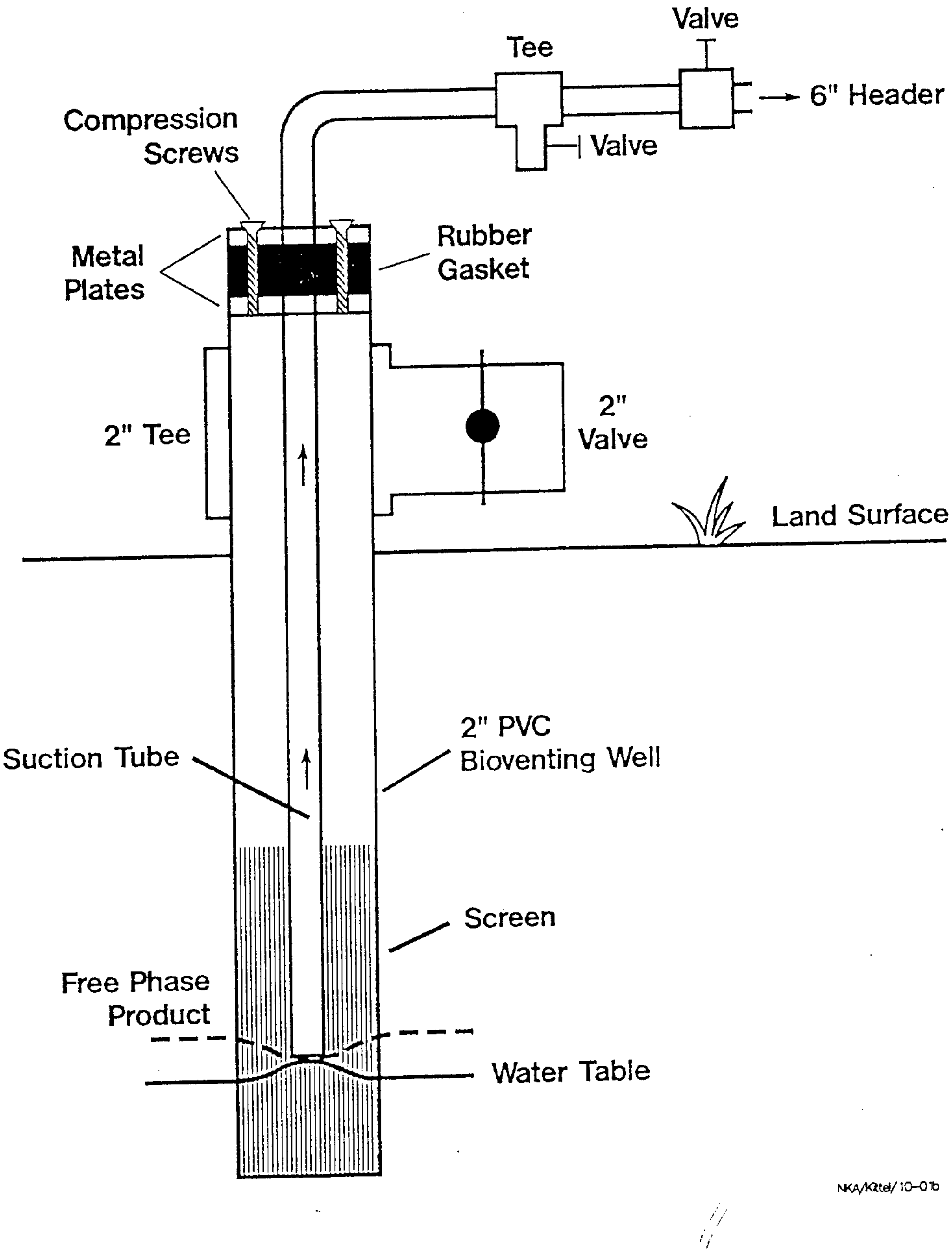

Figure 3. Slurper Tube Placement and Valve Position for the Bioslurper Pump Test

3.1.4.4 Soil Vapor Extraction Test

Prior to test initiation, the drop tube was positioned 6 inches into the well. The liquid ring pump was started at approximately 1115, 16 August 1997, to begin the soil vapor extraction test. The liquid ring pump was supplied with tap water throughout testing. The pump head vacuum was approximately 21.5 inches Hg and the well vacuum was 24 inches H_2O. The vapor flowrate was approximately 12 scfm. The test was discontinued after 4 hours of operation, because water was being extracted through the drop tube.

3.1.4.5 Drawdown Pump Test

Upon termination of the soil vapor extraction test, preparations were made to begin the drawdown pump test. Prior to test initiation, depths to LNAPL and groundwater were measured. The drop tube was placed at a depth of 74.2 ft so that the tip was approximately 3 ft below the oil/water interface with the PVC connecting tee open to the atmosphere (Figure 4). The liquid ring pump and oil/water separator were primed with known amounts of groundwater to ensure that any LNAPL or groundwater entering the system could be quantified. The flow totalizers for the LNAPL and aqueous effluent were zeroed, and the liquid ring pump was started at 1600, 16 August 1997, to begin the drawdown pump test. The test was initiated approximately 1 hour after termination of the soil vapor extraction test and was operated continuously for 41 hours. The pump head vacuum was approximately 23 inches Hg and the temperature-corrected vapor flowrate was approximately 9.6 scfm. The LNAPL and groundwater extraction rates were monitored throughout the test, as were all other relevant data for the drawdown pump test. Test data sheets are provided in Appendix D.

3.1.4.6 Off-Gas Sampling and Analysis

Two soil gas samples were collected from the off-gas during the bioslurper pump test. The samples were collected in Summa® canisters and were labeled NAFB-27-1 and NAFB-27-2. Samples were collected during the bioslurper pump test approximately 20 and 28 hours after test initiation, respectively. The samples were sent under chain of custody to Air Toxics, Ltd., in Rancho Cordova, California, for analyses of BTEX and TPH.

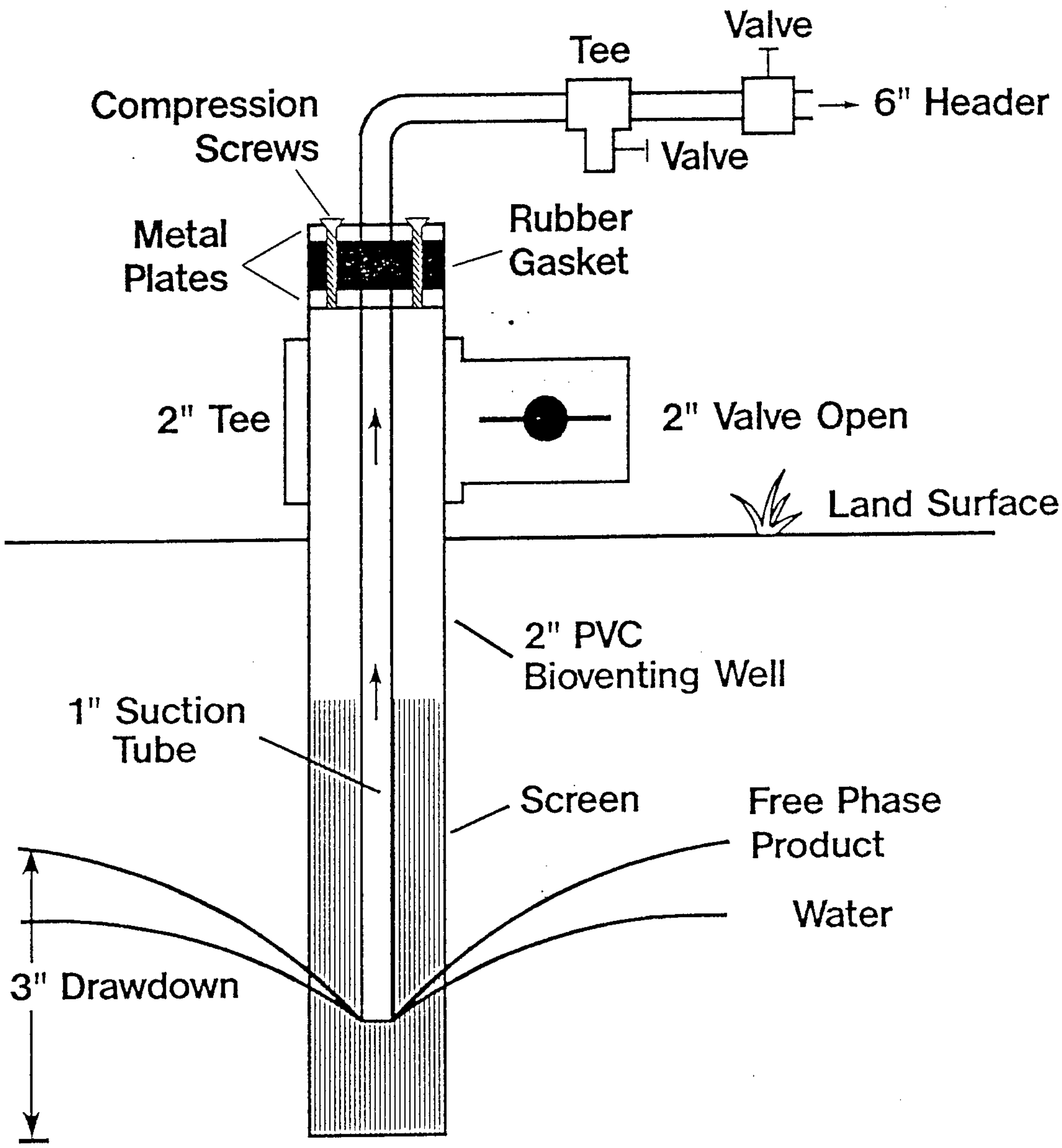

Figure 4. Slurper Tube Placement and Valve Position for the Drawdown Pump Test

3.1.4.7 Groundwater and LNAPL Sampling and Analysis

Two groundwater samples were collected during the bioslurper pump test. The samples were collected from the outlet of the oil/water separator and were labeled NAFB-27-A and NAFB-27-B. Samples were collected during the bioslurper pump test approximately 20 and 72 hours after test initiation, respectively. The samples were collected in 40-mL VOA vials containing HCl preservative. The samples were checked to ensure no headspace was present and were then shipped on ice and sent under chain of custody to Alpha Analytical, Inc., in Sparks, Nevada for analysis of BTEX and TPH.

An LNAPL sample was collected from monitoring well MW-24 immediately following the skimmer pump test and was labeled NAFB-27-FUEL. The sample was sent to Alpha Analytical, Inc., Sparks, Nevada for analysis of BTEX and C-range compounds.

3.1.5 In Situ Respiration Testing

Air containing approximately 2% helium was injected into three monitoring points for approximately 24 hours beginning on 16 August 1997. The setup for the in situ respiration test is described in the Test Plan and Technical Protocol for a Field Treatability Test for Bioventing (Hinchee et al., 1992). A ½-hp diaphragm pump was used for air and helium injection. Air and helium were injected through the following monitoring points at the depths indicated: MPA-55′, MPB-70′, and MPC-55′. After the air/helium injection was terminated, soil gas concentrations of oxygen, carbon dioxide, TPH, and helium were monitored periodically. The in situ respiration test was terminated on 20 August 1997. Oxygen utilization and biodegradation rates were calculated as described in Hinchee et al. (1992). Raw data for these tests are presented in Appendix E.

Helium concentrations were measured during the in situ respiration test to quantify helium leakage to or from the surface around the monitoring points. Helium loss over time is attributable to either diffusion through the soil or leakage. A rapid drop in helium concentration usually indicates leakage. A gradual loss of helium along with a first-order curve generally indicates diffusion. As a rough estimate, the diffusion of gas molecules is inversely proportional to the square root of the molecular weight of the gas. Based on molecular weights of 4 for helium and 32 for oxygen, helium diffuses approximately 2.8 times faster than oxygen, or the diffusion of oxygen is 0.35 times the rate of helium diffusion. As a general rule, we have found that if helium concentrations at test completion

are at least 50 to 60% of the initial levels, measured oxygen uptake rates are representative. Greater helium loss indicates a problem, and oxygen utilization rates are not considered representative.

3.2 Pilot Test Results

This section documents the results of the site characterization, the comparative LNAPL recovery pump test, and other supporting tests conducted at Site 27, Nellis AFB.

3.2.1 Baildown Test Results

Results from the baildown test in monitoring well MW-24 are presented in Table 2. The LNAPL recovery rate was slow initially, however the LNAPL thickness recovered to approximately 93% of initial levels by the end of the 27-hour test period. Pilot testing was initiated in this well to determine if vacuum-enhanced conditions would facilitate free product recovery.

3.2.2 LNAPL Pump Test Results

3.2.2.1 Skimmer Pump Test Results

No significant quantity of LNAPL was recovered during this test. A total of approximately 1 gallon of fuel was recovered during 41.5 hours of continuous pumping (Table 3). Since the skimmer pump test was conducted with a Ferret® downhole product-only recovery pump, groundwater was not extracted during this test. These results indicate that gravity-driven free product recovery was not an effective method for recovering free-phase LNAPL.

3.2.2.2 Bioslurper Pump Test Results

LNAPL recovery remained low during the bioslurper pump test. A total of less than 1 gallon of LNAPL was extracted during the bioslurper pump test (Table 3). Extracted groundwater totaled 8,070 gallons for the 96 hour pump test. During the first day of pumping, the groundwater recovery rate averaged 2,100 gallons/day. This rate remained relatively constant during the remainder of the

Table 2. Results of Baildown Testing in Monitoring Well MW-24, Site 27

Sample Collection Time (Date-Time)	Time from T=0 (hr)	Depth to Groundwater (ft)	Depth to LNAPL (ft)	LNAPL Thickness (ft)
Initial Reading 08/08/97-1830	--	73.67	68.20	5.47
08/09/97-1133	0	69.79	69.79	0.00
08/09/97-1148	0.25	70.18	69.80	0.38
08/09/97-1208	0.58	70.43	69.74	0.69
08/09/97-1452	3.3	71.59	69.44	2.15
08/09/97-1723	5.8	72.20	69.25	2.95
08/10/97-0830	21	73.94	68.98	4.96
08/10/97-1110	24	73.97	68.95	5.02
08/10/97-1408	27	75.10	70.04	5.06

Table 3. Pump Test Results at Monitoring Well MW-24, Site 27

Time (day)	Recovery Rate (gallons/day)					
	Skimmer Pump Test		Bioslurper Pump Test		Drawdown Pump Test	
	LNAPL	Groundwater[1]	LNAPL	Groundwater	LNAPL	Groundwater
1	0	NA	0	2,100	0	2,100
2	0.80[2]	NA	0	2,100	0	1,900
3	NA	NA	0	1,900	NA	NA
4	NA	NA	0.40[2]	2,300	NA	NA
Average (gal/d)	0.47	NA	0.10	2,100	0	2,000
Total Recovery (gal)	0.80	NA	0.40	8,070	0	3,335

NA = Not applicable.
[1] Product only recovery pump used; therefore, no groundwater was extracted.
[2] LNAPL could not be quantified earlier in test due to very low recoveries. Therefore, this reading is more indicative of a cumulative reading over the entire test period.

pump test. These results indicate that vacuum-enhanced recovery was not an effective means for recovering free-phase LNAPL.

Soil gas monitoring points were located too far away from the extraction well to determine whether the vadose zone was being oxygenated during the bioslurper pump test.

3.2.2.3 Drawdown Pump Test

Drawdown pump testing was conducted to determine if a cone of groundwater depression would enhance LNAPL recovery. The water table was depressed approximately 3 ft below the static water table. No free product was recovered during drawdown pumping (Table 3). The groundwater production rate was similar to that observed during bioslurping, with an average rate of 2,000

gallons/day. These results demonstrate that operation of the bioslurper system in the drawdown mode was not an effective means of free-product recovery.

3.2.2.4 Extracted Groundwater, LNAPL, and Off-Gas Analyses

Contaminant concentrations in groundwater were relatively low, with average TPH concentrations of 11 mg/L and average total BTEX concentrations of 2.6 mg/L (Table 4). These values typically meet discharge requirements.

Off-gas samples from the bioslurper system also were collected during the bioslurper pump test. The results from the off-gas analyses are presented in Table 5. Given the temperature-corrected vapor flowrate (6.7 scfm) and vapor concentrations, initial hydrocarbon removal rates were approximately 57 lb/day of TPH and 0.047 lb/day of benzene.

The composition of LNAPL in terms of BTEX and C-range compounds is shown in Tables 6 and 7. The C-range fractionation is also shown in Figure 5.

3.2.3 In Situ Respiration Test Results

Results from the in situ respiration test are presented in Table 8. Oxygen utilization rates ranged from 0.025 to 0.16 $\%O_2$/hr, and biodegradation rates ranged from 0.41 to 2.6 mg/kg-day. The greatest oxygen depletion was seen at the deepest depth of MPB.

3.3 Discussion

The main objective of the field pilot test at Nellis AFB was to determine if LNAPL recovery is feasible and to select the most effective method of LNAPL recovery.

Baildown recovery testing was conducted at monitoring well MW-24. Baildown recovery tests provide a qualitative indication of the presence of mobile, free-phase LNAPL and recovery potential. The baildown recovery test at MW-24 indicated a relatively quick rate of LNAPL recovery into the well and resulted in an LNAPL thickness nearly equal to the initial apparent thickness. Site logistics limited the number of wells which could potentially be used for bioslurper pilot testing; therefore, baildown testing at Site 27 was limited to monitoring well MW-24.

Table 4. **BTEX and TPH Concentrations in Extracted Groundwater During The Bioslurper Pump Test at Site 27**

Parameter	Concentration (mg/L)	
	NAFB-27-A	NAFB-27-B
TPH (Purgeable)	13	9.7
Benzene	0.40	0.31
Toluene	0.82	0.43
Ethylbenzene	0.30	0.13
Total Xylenes	1.8	1.1

Table 5. **BTEX and TPH Concentrations in Off-Gas During the Bioslurper Pump Test at Site 27**

Parameter	Concentration (mg/L)	
	NAFB-27-1	NAFB-27-2
TPH as jet fuel	29,000	37,000
Benzene	49	56
Toluene	120	130
Ethylbenzene	54	65
Total Xylenes	240	280

Table 6. BTEX Concentrations in LNAPL from Site 27

Parameter	Concentration (mg/L)
Benzene	<2,600
Toluene	9,700
Ethylbenzene	4,600
Total Xylenes	27,000

Table 7. C-Range Compounds in LNAPL from Site 27

C-Range Compounds	Percentage of Total
<C6	14.8
C7	19.6
C8	15.6
C9	10.9
C10	10.7
C11	8.5
C12	6.6
C13	5.2
C14	3.9
C15	2.5
C16	1.0
C17	0.36
C18	0.27
>C19	0.14

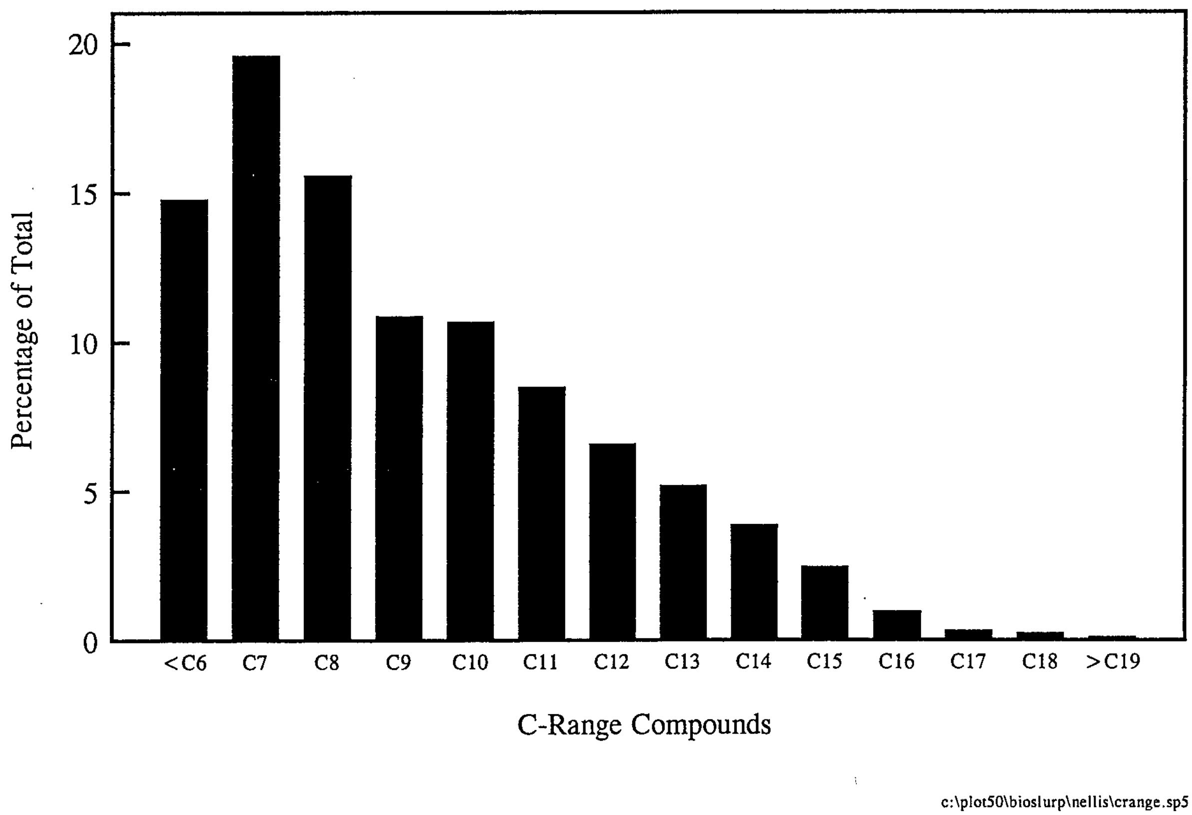

Figure 5. C-Range Compounds in LNAPL from Site 27

Table 8. In Situ Respiration Test Results at Site 27

Monitoring Point	Oxygen Utilization Rate (%/hr)	Biodegradation Rate (mg/kg-day)
MPA-55	0.025	0.41
MPB-70	0.16	2.6
MPC-55	0.040	0.65

None of the LNAPL recovery techniques were successful at recovering free product from MW-24 at Site 27. Less than 1 gallon of fuel each was recovered during the skimmer and the bioslurper pump tests, and no fuel was recovered during the drawdown pump testing. A fuel-only recovery pump was used for the skimmer pump test; therefore, groundwater was not recovered. The groundwater was extracted at a relatively constant recovery rate throughout the bioslurper and drawdown pump tests, with respective rates of 2,100 gallons/day and 2,000 gallons/day.

Bioslurping also promotes mass removal in the form of in situ biodegradation via bioventing and soil gas extraction. Vapor phase mass removal is the result of soil gas extraction as well as volatilization that occurs during the movement of LNAPL free product through the extraction network. Given the measured vapor flowrate (6.7 scfm) and average vapor concentrations at MW-24, initial hydrocarbon removal rates were approximately 57 lb/day of TPH and 0.047 lb/day of benzene.

The initial soil gas profiles at the site displayed relatively oxygen-deficient vapor conditions with high volatile hydrocarbons at all depths of the existing monitoring points. These conditions indicate that natural biodegradation of residual petroleum hydrocarbons has occurred, but is limited by oxygen availability. Soil gas monitoring points were located too far away to determine if the vadose zone was being oxygenated via the bioslurper action. In situ biodegradation rates of 0.41 to 2.6 mg/kg-day were measured at three different locations of the monitoring points. Based on an estimated radius of influence of 70 ft and a hydrocarbon-impacted soil thickness of 70 ft, mass removal rates via biodegradation are on the order of 12 to 78 lbs of hydrocarbon per day. Thus, mass removal rates via biodegradation could be as significant as the initial vapor phase removal rates measured during the bioslurper test. These results indicate that bioventing is feasible at this site. Air injection bioventing is preferable over bioslurping and soil vapor extraction with respect to the elimination of hydrocarbon vapor emissions.

Based on pilot test results from MW-24, implementation of bioslurping or any free-product recovery technique does not appear to facilitate LNAPL recovery. The most appropriate technology for this site may be bioventing to treat significant vadose zone contamination, coupled with periodic baildown of monitoring wells should free product appear.

4.0 FREE PRODUCT RECOVERY TESTING AT SITE 28

4.1 Pilot Test Methods

This section documents the initial conditions at the test site and describes the test equipment and methods used for the short-term pilot test at Site 27, Nellis AFB. Monitoring points were not available at this site; therefore, the in situ respiration test and the soil gas permeability test were not conducted.

4.1.1 Initial LNAPL/Groundwater Measurements and Baildown Testing

Monitoring well MW-31 was evaluated for use in the bioslurper pilot testing. Initial depths to LNAPL and to groundwater were measured using an oil/water interface probe (ORS Model #1068013). LNAPL was removed from the well with a Teflon(r) bailer until the LNAPL thickness could no longer be reduced. The rate of increase in the thickness of the floating LNAPL layer was monitored using the oil/water interface probe for approximately 5 hours.

4.1.2 Well Construction Details

A short-term bioslurper pump test was conducted at existing monitoring well MW-31 at Site 28. The well is constructed of 2-inch-diameter, schedule 40 polyvinyl chloride (PVC), however precise details of the depth and screened interval are not available.

4.1.3 LNAPL Recovery Testing

4.1.3.1 System Setup

The bioslurping pilot test system is a trailer-mounted mobile unit. The vacuum pump (Atlantic Fluidics Model A100, 7.5-hp liquid ring pump), oil/water separator, and required support equipment were transported to the test location on a trailer. The trailer was located near monitoring well MW-31, the well cap was removed, a coupling and tee were attached to the top of the well, and the drop tube was lowered into the well. The drop tube was attached to the vacuum pump. Different configurations of the tee and the placement depth of the slurper tube allow for simulation of skimmer pumping, operation in the bioslurping configuration, or simulation of drawdown pumping. Extracted groundwater was treated by passing the effluent through a filter box, an oil/water separator, a 325 gallon tank, a 2,000 gallon tank, and then transported to Site 27 and pumped into the existing OHM oil/water separator. Extracted soil gas was discharged directly to the atmosphere.

A brief system startup test was performed prior to LNAPL recovery testing to ensure that all system components were working properly. The system checklist is provided in Appendix C. All site data and field testing information were recorded in a field notebook and then transcribed onto pilot test data sheets provided in Appendix D.

4.1.3.2 Skimmer Pump Test

Prior to test initiation, depths to LNAPL and groundwater were measured. The skimmer pump test was conducted as described in Section 3.1.4.2. The pump was started at 1600, 12 August 1997 to begin the skimmer pump test. The test was operated continuously for 41.5 hours. The LNAPL extraction rate was monitored throughout the test, as were all other relevant data for the skimmer pump test. Test data sheets are provided in Appendix D.

4.1.3.3 Bioslurper Pump Test

Prior to test initiation, depths to LNAPL and groundwater were measured. The slurper tube was then set at the LNAPL/groundwater interface at a depth of 63.45 ft. The setup for the bioslurper pump test was the same as described in Section 3.1.4.3. The liquid ring pump was started at 1130,

14 August 1997 to begin the bioslurper pump test. The test was initiated 2 hours after the skimmer pump test and was operated continuously for approximately 95 hours. The pump head vacuum was approximately 21 inches Hg and the well head vacuum was approximately 46 inches H_2O. The temperature-corrected vapor flowrate was approximately 9.5 scfm. The LNAPL and groundwater extraction rates were monitored throughout the test, as were all other relevant data for the bioslurper pump test. Test data sheets are provided in Appendix D.

4.1.3.4 Drawdown Pump Test

Upon completion of the bioslurper pump test, preparations were made to begin the drawdown pump test. Prior to test initiation, depths to LNAPL and groundwater were measured. The drop tube was placed at a depth of 66.5 ft so that the tip was approximately 3 ft below the oil/water interface. The drawdown pump test then was conducted as described in Section 3.1.4.5. The liquid ring pump was started at 1115, 18 August 1997 to begin the drawdown pump test. The test was initiated approximately 0.5 hour after the bioslurper pump test and was operated continuously for approximately 26 hours. The pump head vacuum was approximately 20 inches Hg and the temperature-corrected vapor flowrate was approximately 12 scfm. The LNAPL and groundwater extraction rates were monitored throughout the test, as were all other relevant data for the drawdown pump test. Test data sheets are provided in Appendix D.

4.1.3.5 Off-Gas Sampling and Analysis

Two soil gas samples were collected from the off-gas during the bioslurper pump test. The samples were collected in Summa® canisters, and were labeled NAFB-28-1 and NAFB-28-2. Samples were collected during the bioslurper pump test approximately 21 and 93 hours after test initiation, respectively. The samples were sent under chain of custody to Air Toxics, Ltd., in Rancho Cordova, California, for analyses of BTEX and TPH.

4.1.3.6 Groundwater Sampling and Analysis

Two groundwater samples were collected during the bioslurper pump test. The samples were collected from the outlet of the oil/water separator approximately 23.5 and 93 hours after initiation of

bioslurping and were labeled NAFB-28-A and NAFB-28-B, respectively. The samples were collected in 40-mL VOA vials containing HCl preservative. The samples were checked to ensure no headspace was present and were then shipped on ice and sent under chain of custody to Alpha Analytical, Inc., in Sparks, Nevada for analyses of BTEX and TPH.

4.2 Pilot Test Results

This section documents the results of the site characterization, the comparative LNAPL recovery pump test, and other supporting tests conducted at Site 28, Nellis AFB.

4.2.1 Baildown Test Results

Results from the baildown test in monitoring well MW-31 are presented in Table 9. The LNAPL recovery rate was low, with the LNAPL thickness recovering to approximately 16% of initial levels by the end of the 26.5-hour test period. Pilot testing was initiated in this well to determine if vacuum-enhanced conditions would facilitate free product recovery.

4.2.2 LNAPL Pump Test Results

4.2.2.1 Skimmer Pump Test

No significant quantity of LNAPL was recovered during this test. A total of less than 1 gallon of fuel was recovered during 41.5 hours of continuous pumping (Table 10). Since the skimmer pump test was conducted with a Ferret® downhole product-only recovery pump, groundwater was not extracted during this test.

4.2.2.2 Bioslurper Pump Test

No LNAPL was recovered during the bioslurper pump test (Table 10). Extracted groundwater totaled 3,333 gallons for the 95 hour pump test. During the first day of pumping, the groundwater recovery rate averaged 800 gallons/day. This rate remained relatively constant during the remainder of the pump test.

Table 9. Results of Baildown Testing in Monitoring Well MW-31, Site 28

Sample Collection Time (Date-Time)	Time from T=0 (hr)	Depth to Groundwater (ft)	Depth to LNAPL (ft)	LNAPL Thickness (ft)
Initial Reading 08/09/97-1000	--	67.89	60.89	7.00
08/09/97-1022	0	63.32	62.73	0.59
08/09/97-1025	0.05	63.20	62.47	0.73
08/09/97-1037	0.25	63.12	62.31	0.81
08/09/97-1220	1.97	63.19	62.24	0.95
08/09/97-1430	4.13	63.17	62.19	0.98
08/10/97-1130	25.13	63.29	62.20	1.09
08/11/97-1600	53.63	63.24	62.15	1.09
08/12/97-1515	76.88	63.31	62.18	1.13

Table 10. Pump Test Results at Monitoring Well MW-24, Site 27

Time (day)	Recovery Rate (gallons/day)					
	Skimmer Pump Test		Bioslurper Pump Test		Drawdown Pump Test	
	LNAPL	Groundwater[1]	LNAPL	Groundwater	LNAPL	Groundwater
1	0	NA	0	800	0	830
2	0.66[2]	NA	0	730	NA	NA
3	NA	NA	0	920	NA	NA
4	NA	NA	0	900	NA	NA
Average (gal/d)	0.38	NA	0	840	0	830
Total Recovery (gal)	0.66	NA	0	3,333	0	891

NA = Not applicable.

[1] Product only recovery pump used; therefore, no groundwater was extracted.

[2] LNAPL could not be quantified earlier in test due to very low recoveries. Therefore, this reading is more indicative of a cumulative reading over the entire test period.

4.2.2.3 Drawdown Pump Test

Drawdown pump testing was conducted to determine if a cone of groundwater depression would enhance LNAPL recovery. The water table was depressed approximately 3 ft below the static water table. No free product was recovered during approximately 26 hours of drawdown pumping (Table 10). The groundwater production rate was similar to that observed during bioslurping, with an average rate of 830 gallons/day.

4.2.2.4 Extracted Groundwater, LNAPL, and Off-Gas Analyses

Contaminant concentrations in groundwater were relatively low, with TPH concentrations ranging from 12 mg/L to less than the detection limit and an average total BTEX concentration of 8.2 mg/L (Table 11). These values typically meet discharge requirements.

Off-gas samples from the bioslurper system also were collected during the bioslurper pump test. The results from the off-gas analyses are presented in Table 12. Given the measured vapor flowrate (9.5 scfm) and vapor concentrations, initial hydrocarbon removal rates were approximately 320 lb/day of TPH and 0.49 lb/day of benzene.

The composition of LNAPL in terms of BTEX and C-range compounds is shown in Tables 13 and 14. The C-range fractionation is also shown in Figure 6.

4.3 Discussion

The main objective of the field pilot test at Site 28, Nellis AFB was to determine if LNAPL recovery is feasible and to select the most effective method of LNAPL recovery.

Baildown recovery testing was conducted at monitoring well MW-31. Baildown recovery tests provide a qualitative indication of the presence of mobile, free-phase LNAPL and recovery potential. The baildown recovery test at MW-31 indicated a relatively slow rate of LNAPL recovery and resulted in an LNAPL thickness substantially less than the initial apparent thickness. Site logistics limited the number of wells which could potentially be used for bioslurper pilot testing; therefore, baildown testing at Site 28 was limited to monitoring well MW-31.

None of the LNAPL recovery techniques were successful at recovering free product from MW-31 at Site 28. Less than 1 gallon of fuel was recovered throughout the entire sequence of pump tests. A fuel-only recovery pump also was used for the skimmer pump test at MW-31, therefore groundwater was not recovered during this recovery test. The groundwater was extracted at a relatively constant recovery rate throughout the bioslurper and drawdown pump tests, with respective rates of 840 gallons/day and 830 gallons/day.

Bioslurping also promotes mass removal in the form of in situ biodegradation via bioventing and soil gas extraction. Vapor phase mass removal is the result of soil gas extraction as well as volatilization that occurs during the movement of LNAPL free product through the extraction

Table 11. **BTEX and TPH Concentrations in Extracted Groundwater During the Bioslurper Pump Test at Site 28**

Parameter	Concentration (mg/L)	
	NAFB-28-A	NAFB-28-B
TPH (Purgeable)	12	<25
Benzene	2.1	3.6
Toluene	2.9	5.0
Ethylbenzene	0.11	0.17
Total Xylenes	0.99	1.6

Table 12. **BTEX and TPH Concentrations in Off-Gas During the Bioslurper Pump Test at Site 28**

Parameter	Concentration (mg/L)	
	NAFB-28-1	NAFB-28-2
TPH as jet fuel	120,000	140,000
Benzene	320	470
Toluene	540	730
Ethylbenzene	57	63
Total Xylenes	300	320

Table 13. BTEX Concentrations in LNAPL from Site 28

Parameter	Concentration (mg/L)
Benzene	<2,600
Toluene	18,000
Ethylbenzene	4,100
Total Xylenes	29,000

Table 14. C-Range Compounds in LNAPL from Site 28

C-Range Compounds	Percentage of Total
<C6	8.4
C7	12.2
C8	9.5
C9	7.4
C10	9.0
C11	10.7
C12	11.5
C13	10.6
C14	9.4
C15	6.5
C16	3.0
C17	1.0
C18	0.51
>C19	0.31

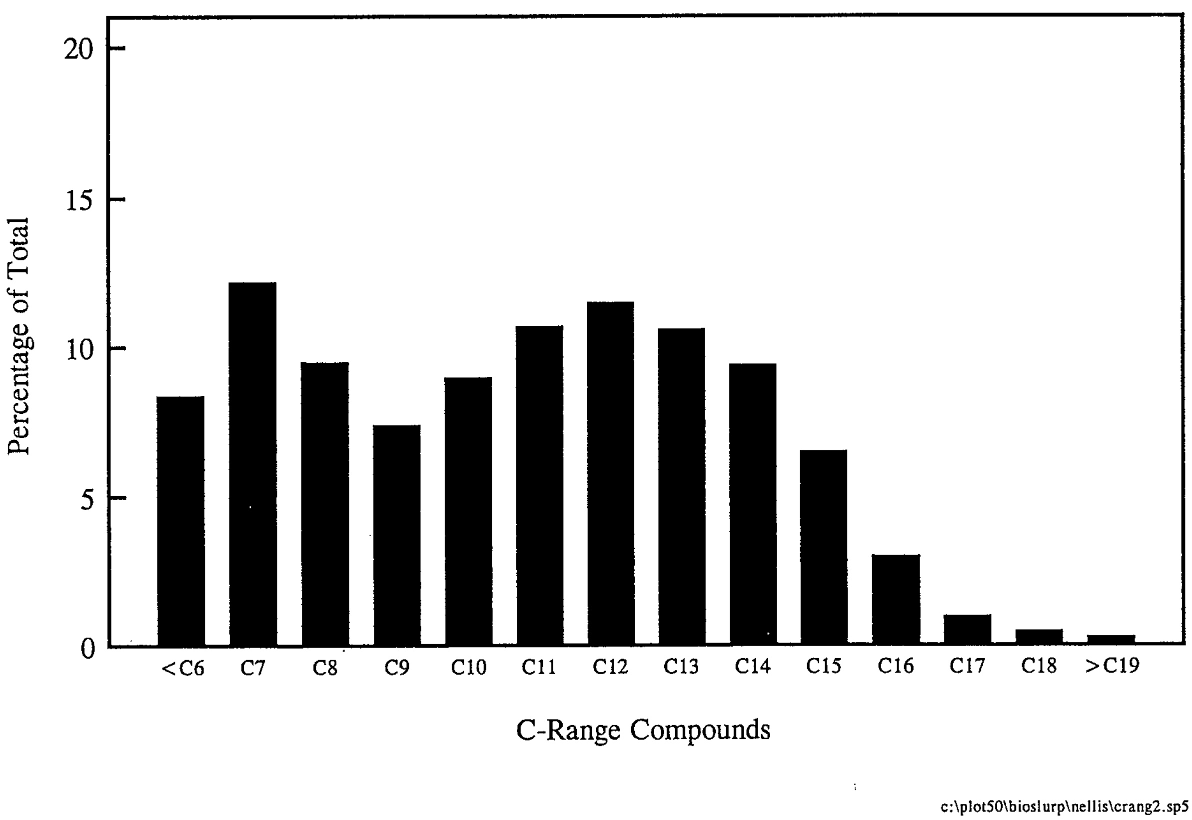

Figure 6. C-Range Compounds in LNAPL from Site 28

network. Given the measured vapor flowrate (9.5 scfm) and average vapor concentrations at MW-31, initial hydrocarbon removal rates were approximately 320 lb/day of TPH and 0.49 lb/day of benzene.

Based on pilot test results from MW-31, implementation of bioslurping or any free-product recovery technique does not appear to facilitate LNAPL recovery. Although an in situ respiration test could not be conducted, based on off-gas concentrations, it is possible that bioventing would be effective at remediating the vadose zone soils. Periodic baildown of monitoring wells may be the most effective means for handling the periodic appearance of free product.

5.0 REFERENCES

Battelle. 1995. Test Plan and Technical Protocol for Bioslurping, Report prepared by Battelle Columbus Operations for the U.S. Air Force Center for Environmental Excellence, Brooks Air Force Base, Texas.

Hinchee, R.E., S.K. Ong, R.N. Miller, D.C. Downey, and R. Frandt. 1992. Test Plan and Technical Protocol for a Field Treatability Test for Bioventing (Rev. 2), Report prepared by Battelle Columbus Operations, U.S. Air Force Center for Environmental Excellence, and Engineering Sciences, Inc. for the U.S. Air Force Center for Environmental Excellence, Brooks Air Force Base, Texas.

Montgomery Watson, 1993a. Installation Restoration Program Site 27 Remedial Investigation, Final. Prepared by Montgomery Watson for U.S. Army Corps of Engineers, Omaha District.

Montgomery Watson, 1993b. Interim Remedial Action/Pilot Study for Site 28, Work Plan for the Pilot Extraction System, Final. Prepared by Montgomery Watson for U.S. Army Corps of Engineers, Omaha District.

APPENDIX A

SITE-SPECIFIC TEST PLAN FOR BIOSLURPER FIELD ACTIVITIES AT NELLIS AFB, NEVADA

APPENDIX B

LABORATORY ANALYTICAL REPORTS

@AIR TOXICS LTD.

AN ENVIRONMENTAL ANALYTICAL LABORATORY

WORK ORDER #: 9708239

Work Order Summary

CLIENT:	Mr. Jerry Tompkins Battelle 505 King Avenue Columbus, OH 43201	**BILL TO:**	Same
PHONE:	614-424-4996	**P.O. #**	
FAX:	614-424-3667	**PROJECT #**	G462201-30 D0601 Bioslurper Nellis AFB
DATE RECEIVED:	8/19/97		
DATE COMPLETED:	8/28/97		

FRACTION #	NAME	TEST	RECEIPT VAC./PRES.
01A	NAFB-27-1 # 11439	TO-3	4.0 "Hg
02A	NAFB-27-2 # 11428	TO-3	5.0 "Hg
03A	NAFB-28-1 # 11445	TO-3	4.5 "Hg
04A	NAFB-28-2 # 13899	TO-3	5.5 "Hg
05A	Lab Blank	TO-3	NA
05B	Lab Blank	TO-3	NA

CERTIFIED BY: Robert Coome
Laboratory Director

DATE: 8/28/97

Certification numbers: CA ELAP - 1149, NY ELAP - 11291, UT ELAP - E-217

180 BLUE RAVINE ROAD, SUITE B FOLSOM, CA 95630
(916) 985-1000 • (800) 985-5955 • FAX (916) 985-1020

AIR TOXICS LTD.

SAMPLE NAME: NAFB-27-1 # 11439

ID#: 9708239-01A

EPA METHOD TO-3

(Aromatic Volatile Organics in Air)

GC/PID

File Name: 6082714 Date of Collection: 8/13/97

Dil. Factor: 2330 Date of Analysis: 8/27/97

Compound	Rpt. Limit (ppmv)	Rpt. Limit (uG/L)	Amount (ppmv)	Amount (uG/L)
Benzene	2.3	7.6	49	160
Toluene	2.3	8.9	120	460
Ethyl Benzene	2.3	10	54	240
Total Xylenes	2.3	10	240 M	1000 M

TOTAL PETROLEUM HYDROCARBONS

GC/FID

(Quantitated as Jet Fuel)

File Name: 6082714 Date of Collection: 8/13/97

Dil. Factor: 2330 Date of Analysis: 8/27/97

Compound	Rpt. Limit (ppmv)	Rpt. Limit (uG/L)	Amount (ppmv)	Amount (uG/L)
TPH* (C5+ Hydrocarbons)	23	150	29000	190000
C2 - C4** Hydrocarbons	23	43	1500	2700

*TPH referenced to Jet Fuel (MW=156)

**C2 - C4 Hydrocarbons referenced to Propane (MW=44)

M = Reported value may be biased due to apparent matrix interferences.

Container Type: 1 Liter Summa Canister

AIR TOXICS LTD.

SAMPLE NAME: NAFB-27-2 # 11428

ID#: 9708239-02A

EPA METHOD TO-3

(Aromatic Volatile Organics in Air)

GC/PID

File Name: 6082712 — Date of Collection: 8/13/97

Dil. Factor: 1210 — Date of Analysis: 8/27/97

Compound	Rpt. Limit (ppmv)	Rpt. Limit (uG/L)	Amount (ppmv)	Amount (uG/L)
Benzene	1.2	3.9	56	180
Toluene	1.2	4.6	130	500
Ethyl Benzene	1.2	5.3	65	290
Total Xylenes	1.2	5.3	280 M	1200 M

TOTAL PETROLEUM HYDROCARBONS

GC/FID

(Quantitated as Jet Fuel)

File Name: 6082712 — Date of Collection: 8/13/97

Dil. Factor: 1210 — Date of Analysis: 8/27/97

Compound	Rpt. Limit (ppmv)	Rpt. Limit (uG/L)	Amount (ppmv)	Amount (uG/L)
TPH* (C5+ Hydrocarbons)	12	78	37000	240000
C2 - C4** Hydrocarbons	12	22	1700	3100

*TPH referenced to Jet Fuel (MW=156)

**C2 - C4 Hydrocarbons referenced to Propane (MW=44)

M = Reported value may be biased due to apparent matrix interferences.

Container Type: 1 Liter Summa Canister

AIR TOXICS LTD.

SAMPLE NAME: NAFB-28-1 # 11445

ID#: 9708239-03A

EPA METHOD TO-3

(Aromatic Volatile Organics in Air)

GC/PID

File Name:	6082516		Date of Collection: 8/15/97	
Dil. Factor:	5950		Date of Analysis: 8/25/97	
Compound	**Rpt. Limit (ppmv)**	**Rpt. Limit (uG/L)**	**Amount (ppmv)**	**Amount (uG/L)**
Benzene	6.0	19	320	1000
Toluene	6.0	23	540	2100
Ethyl Benzene	6.0	26	57	250
Total Xylenes	6.0	26	300 M	1300 M

TOTAL PETROLEUM HYDROCARBONS

GC/FID

(Quantitated as Jet Fuel)

File Name:	6082516		Date of Collection: 8/15/97	
Dil. Factor:	5950		Date of Analysis: 8/25/97	
Compound	**Rpt. Limit (ppmv)**	**Rpt. Limit (uG/L)**	**Amount (ppmv)**	**Amount (uG/L)**
TPH* (C5+ Hydrocarbons)	60	390	120000	780000
C2 - C4** Hydrocarbons	60	110	1600	2900

*TPH referenced to Jet Fuel (MW=156)

**C2 - C4 Hydrocarbons referenced to Propane (MW=44)

M = Reported value may be biased due to apparent matrix interferences.

Container Type: 1 Liter Summa Canister

AIR TOXICS LTD.

SAMPLE NAME: NAFB-28-2 # 13899

ID#: 9708239-04A

EPA METHOD TO-3

(Aromatic Volatile Organics in Air)

GC/PID

File Name:	6082517		Date of Collection: 8/18/97	
Dil. Factor:	6180		Date of Analysis: 8/25/97	
Compound	**Rpt. Limit (ppmv)**	**Rpt. Limit (uG/L)**	**Amount (ppmv)**	**Amount (uG/L)**
Benzene	6.2	20	470	1500
Toluene	6.2	24	730	2800
Ethyl Benzene	6.2	27	63	280
Total Xylenes	6.2	27	320 M	1400 M

TOTAL PETROLEUM HYDROCARBONS

GC/FID

(Quantitated as Jet Fuel)

File Name:	6082517		Date of Collection: 8/18/97	
Dil. Factor:	6180		Date of Analysis: 8/25/97	
Compound	**Rpt. Limit (ppmv)**	**Rpt. Limit (uG/L)**	**Amount (ppmv)**	**Amount (uG/L)**
TPH* (C5+ Hydrocarbons)	62	400	140000	910000
C2 - C4** Hydrocarbons	62	110	1100	2000

*TPH referenced to Jet Fuel (MW=156)

**C2 - C4 Hydrocarbons referenced to Propane (MW=44)

M = Reported value may be biased due to apparent matrix interferences.

Container Type: 1 Liter Summa Canister

AIR TOXICS LTD.

SAMPLE NAME: Lab Blank

ID#: 9708239-05A

EPA METHOD TO-3

(Aromatic Volatile Organics in Air)

GC/PID

File Name:	6082509		Date of Collection: NA	
Dil. Factor:	1.00		Date of Analysis: 8/25/97	
Compound	**Rpt. Limit (ppmv)**	**Rpt. Limit (uG/L)**	**Amount (ppmv)**	**Amount (uG/L)**
Benzene	0.001	0.003	Not Detected	Not Detected
Toluene	0.001	0.004	Not Detected	Not Detected
Ethyl Benzene	0.001	0.004	Not Detected	Not Detected
Total Xylenes	0.001	0.004	Not Detected	Not Detected

TOTAL PETROLEUM HYDROCARBONS

GC/FID

(Quantitated as Jet Fuel)

File Name:	6082509		Date of Collection: NA	
Dil. Factor:	1.00		Date of Analysis: 8/25/97	
Compound	**Rpt. Limit (ppmv)**	**Rpt. Limit (uG/L)**	**Amount (ppmv)**	**Amount (uG/L)**
TPH* (C5+ Hydrocarbons)	0.010	0.065	Not Detected	Not Detected
C2 - C4** Hydrocarbons	0.010	0.018	Not Detected	Not Detected

*TPH referenced to Jet Fuel (MW=156)

**C2 - C4 Hydrocarbons referenced to Propane (MW=44)

Container Type: NA

AIR TOXICS LTD.

SAMPLE NAME: Lab Blank
ID#: 9708239-05B

EPA METHOD TO-3
(Aromatic Volatile Organics in Air)

GC/PID

File Name: 6082711			**Date of Collection:** NA	
Dil. Factor: 1.00			**Date of Analysis:** 8/27/97	

Compound	Rpt. Limit (ppmv)	Rpt. Limit (uG/L)	Amount (ppmv)	Amount (uG/L)
Benzene	0.001	0.003	Not Detected	Not Detected
Toluene	0.001	0.004	Not Detected	Not Detected
Ethyl Benzene	0.001	0.004	Not Detected	Not Detected
Total Xylenes	0.001	0.004	Not Detected	Not Detected

TOTAL PETROLEUM HYDROCARBONS
GC/FID
(Quantitated as Jet Fuel)

File Name: 6082711			**Date of Collection:** NA	
Dil. Factor: 1.00			**Date of Analysis:** 8/27/97	

Compound	Rpt. Limit (ppmv)	Rpt. Limit (uG/L)	Amount (ppmv)	Amount (uG/L)
TPH* (C5+ Hydrocarbons)	0.010	0.065	Not Detected	Not Detected
C2 - C4** Hydrocarbons	0.010	0.018	Not Detected	Not Detected

*TPH referenced to Jet Fuel (MW=156)
**C2 - C4 Hydrocarbons referenced to Propane (MW=44)

Container Type: NA

AIR TOXICS LTD.
AN ENVIRONMENTAL ANALYTICAL LABORATORY

180 BLUE RAVINE ROAD, SUITE B
FOLSOM, CA 95630-4719
(916) 985-1000 FAX: (916) 985-1020

CHAIN-OF-CUSTODY RECORD

Nº 11987 Page 1 of 1

Contact Person: Al Pollack
Company: Battelle
Address: City: Columbus State: OH Zip:
Phone: FAX: (614) 424-3667
Collected By: Signature: Shane Walton / Jon Elastep

Project info:
P.O. #:
Project #: CHL2201-30Del01
Project Name: Bioslurper Nellis AFB

Turn Around Time:
☒ Normal
☐ Rush ______ Specify

Lab I.D.	Field Sample I.D.	Date & Time	Analyses Requested	Canister Pressure / Vacuum Initial	Final	Receipt
01A	NAFB-27-1 #11439	13AUG97 / 0830	BTEX / TPH			4.0"Hg
02A	NAFB-27-2 #11428	13 AUG97 / 1515	BTEX / TPH			5.0"Hg
03A	NAFB-28-1 #11445	15 AUG / 0914	BTEX / TPH			4.5"Hg
04A	NAFB-28-2 #13899	18 AUG / 0830	BTEX / TPH			5.5"Hg
						8/19/97

Relinquished By: (Signature) Date/Time: [signature] 18 AUG97 / 0900 Print Name: Errol Headington
Relinquished By: (Signature) Date/Time: Received By: (Signature) Date/Time:
Relinquished By: (Signature) Date/Time: Received By: (Signature) Date/Time: [signature] ATL 8/19/97 0915

Notes:

Lab Use Only	Shipper Name	Air Bill #	Opened By:	Date/Time	Temp. (°C)	Condition	Custody Seals Intact?	Work Order #
	Fed Exp	4844453563	CK	8/19/97 0915	Ambient	good	Yes No None N/A	970823

Alpha Analytical, Inc.
255 Glendale Avenue, Suite 21
Sparks, Nevada 89431
(702) 355-1044
FAX: (702) 355-0406
1-800-283-1183

e-mail: alpha@powernet.net
http//www.powernet.net/~alpha

Las Vegas, Nevada
(702) 498-3312
FAX: (702) 736-7523
Sacramento, California
(916) 366-9089
FAX: (916) 366-9138

ANALYTICAL REPORT

Battelle
505 King Ave
Columbus Ohio 43201

Job#: G462201-30D0601
Phone: (614) 424-6199
Attn: Al Pollock

Sampled: 08/13-15/97 Received: 08/19/97 Analyzed: 08/25/97

Matrix: [ ] Soil [X] Water [ ] Waste

Analysis Requested: TPH - Total Petroleum Hydrocarbons-Purgeable Quantitated As Gasoline
BTEX - Benzene,Toluene,Ethylbenzene,Xylenes

Methodology: TPH - Modified 8015/DHS LUFT Manual/BLS-191
BTEX - Method 624/8240

Results:

Client ID/ Lab ID	Parameter	Concentration	Detection Limit
NAFB-27-A /BMI97081905-01	TPH (Purgeable)	13	2.5 mg/L
	Benzene	400	25 ug/L
	Toluene	820	25 ug/L
	Ethylbenzene	300	25 ug/L
	Total Xylenes	1,800	25 ug/L
NAFB-28-A /BMI97081905-02	TPH (Purgeable)	12	2.5 mg/L
	Benzene	2,100	25 ug/L
	Toluene	2,900	25 ug/L
	Ethylbenzene	110	25 ug/L
	Total Xylenes	990	25 ug/L
NAFB-27-B /BMI97081905-03	TPH (Purgeable)	9.7	2.5 mg/L
	Benzene	310	25 ug/L
	Toluene	430	25 ug/L
	Ethylbenzene	130	25 ug/L
	Total Xylenes	1,100	25 ug/L

ND - Not Detected

Approved by: Roger L. Scholl Date: 8/27/97
Roger L. Scholl, Ph.D.
Laboratory Director

Billing Information:

Name

Address

City, State, Zip

Phone Number ? Fax

Alpha Analytical, Inc.
255 Glendale Avenue, Suite 21
Sparks, Nevada 89431
Phone (702) 355-1044
Fax (702) 355-0406

Client Name Battelle	P.O. #	Job # G462201-30DO01	
Address	PWS #	DWR #	
City, State, Zip	Phone #	Fax #	

Sampled by Client

Report Attention Al Pollack

Analyses Required

Time Sampled	Date Sampled	Matrix* See Key Below	Office Use Only Lab ID Number	Sample Description	Total and type of containers ** See below	TPH/8P	BTXE						REMARKS
	8/13	AQ	BMI9708190501	NAFB-27-A	3V	X	X						
	8/15	✓	02	NAFB-28-A	3V	X	X						
	8/15	✓	03	NAFB-27-B	3V	X	X						

SPECIAL INSTRUCTIONS:

COC broken

15'

	Signature	Print Name	Company	Date	Time
Relinquished by					
Received by	[signature]	Linda Watson	AAI	8/19/97	0800
Relinquished by					
Received by					
Relinquished by					
Received by					

NOTE: Samples are discarded 60 days after results are reported unless other arrangements are made. Hazardous samples will be returned to client or disposed of at client expense.

Alpha Analytical, Inc.
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1-800-283-1183

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http//www.powernet.net/~alpha

Las Vegas, Nevada
(702) 498-3312
FAX: (702) 736-7523
Sacramento, California
(916) 366-9089
FAX: (916) 366-9138

ANALYTICAL REPORT

Battelle
505 King Ave
Columbus Ohio 43201

Job#: G462201-30D0601
Phone: (614) 424-6199
Attn: Al Pollock

Sampled: 08/18/97 Received: 08/19/97 Analyzed: 08/23/97

Matrix: [ ] Soil [X] Water [ ] Waste

Analysis Requested: TPH - Total Petroleum Hydrocarbons-Purgeable Quantitated As Gasoline
BTEX - Benzene, Toluene, Ethylbenzene, Xylenes

Methodology: TPH - Modified 8015/DHS LUFT Manual/BLS-191
BTEX - Method 624/8240

Results:

Client ID/ Lab ID	Parameter	Concentration	Detection Limit
NAFB-28-B	TPH (Purgeable)	ND	25 mg/L
/BMI97081904-01	Benzene	3,600	50 ug/L
	Toluene	5,000	50 ug/L
	Ethylbenzene	170	50 ug/L
	Total Xylenes	1,600	50 ug/L

ND - Not Detected

Approved by: Roger L. Scholl Date: 8/26/97
Roger L. Scholl, Ph.D.
Laboratory Director

Battelle
Columbus Laboratories

CHAIN OF CUSTODY RECORD

Form No. 003

Proj. No.	Project Title
G462201-30D0601	Nellis AFB / Bioslurper

SAMPLERS: (Signature)

DATE	TIME	SAMPLE I.D.	TPH GAS	BTEX	Container No.	Number of Containers	Remarks
18AUG97	0820	NAFB-28-B	X	X		3	
		TRIP BLANK		HOLD			

Relinquished by: (Signature)	Date/Time		Received by: (Signature)	Relinquished by: (Signature)	Date/Time		Received by: (Signature)
	18AUG	0900					
Relinquished by: (Signature)	Date/Time		Received by: (Signature)	Relinquished by: (Signature)	Date/Time		Received by: (Signature)
Relinquished by: (Signature)	Date/Time		Received for Laboratory by: (Signature)	Date/Time		Remarks	
				8/19/97	0800	Results to Al Pollack Battelle FAX (614) 424-3667	

Billing Information:

Name

Address

City, State, Zip

Phone Number ? Fax

Alpha Analytical, Inc.
255 Glendale Avenue, Suite 21
Sparks, Nevada 89431
Phone (702) 355-1044
Fax (702) 355-0406

Page # 1 of 1

Client Name Battelle	P.O. #	Job # G46220I-30DD601
Address	PWS #	DWR #
City, State, Zip	Phone #	Fax #

Sampled by Client

Report Attention Al Pollack

Analyses Required

Time Sampled	Date Sampled	Matrix* See Key Below	Office Use Only Lab ID Number	Sample Description	Total and type of containers ** See below	TPHGAS	BTXE						REMARKS
	8/18	AQ	BMI97081904-01	NAFB-28-B	3V	X	X						
	8/1	✓	02	Trip Blank	1V								

SPECIAL INSTRUCTIONS:

COC broken

	Signature	Print Name	Company	Date	Time
Relinquished by					
Received by	[signature]	Linda Watson	AA	8/19/97	0800
Relinquished by					
Received by					
Relinquished by					
Received by					

NOTE: Samples are discarded 60 days after results are reported unless other arrangements are made. Hazardous samples will be returned to client or disposed of at client expense.

Alpha Analytical, Inc.
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2505 Chandler Avenue, Suite 1
Las Vegas, Nevada 89120
(702) 498-3312
FAX: 702-736-7523
1-800-283-1183

ANALYTICAL REPORT

Battelle
505 King Ave
Columbus Ohio 43201

Job#: G462201-30D0601
Phone: (614) 424-6199
Attn: Al Pollack

Alpha Analytical Number: BMI97081908-01

Client I.D. Number: NAFB-27-Fuel

Date Sampled: 08/12/97

Date Received: 08/19/97

Compound	Method	Concentration mg/Kg	Detection Limit mg/Kg	Date Analyzed
Benzene	8240	ND	2,600	08/22/97
Toluene	8240	9,700	2,600	08/22/97
Total Xylenes	8240	27,000	2,600	08/22/97
Ethylbenene	8240	4,600	2,600	08/22/97
C-range Compounds	Method	Percentage of Total	Detection Limit (Not Applicable)	Date Analyzed
≤C06	GC/FID	14.84	NA	09/10/97
C07	GC/FID	19.60	NA	09/10/97
C08	GC/FID	15.57	NA	09/10/97
C09	GC/FID	10.88	NA	09/10/97
C10	GC/FID	10.67	NA	09/10/97
C11	GC/FID	8.54	NA	09/10/97
C12	GC/FID	6.56	NA	09/10/97
C13	GC/FID	5.19	NA	09/10/97
C14	GC/FID	3.85	NA	09/10/97
C15	GC/FID	2.52	NA	09/10/97
C16	GC/FID	1.02	NA	09/10/97
C17	GC/FID	0.36	NA	09/10/97
C18	GC/FID	0.27	NA	09/10/97
C19 >	GC/FID	0.14	NA	09/10/97

Approved by: Walter Hinchman

Walter Hinchman, Jr.
Qaulity Assurance Officer

Date: 9/10/97

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ANALYTICAL REPORT

Battelle
505 King Ave
Columbus Ohio 43201

Job#: G462201-30D0601
Phone: (614) 424-6199
Attn: Al Pollack

Alpha Analytical Number: BMI97081908-02

Client I.D. Number: NAFB-28-Fuel

Date Sampled: 08/14/97

Date Received: 08/19/97

Compound	Method	Concentration mg/Kg	Detection Limit mg/Kg	Date Analyzed
Benzene	8240	ND	2,600	08/22/97
Toluene	8240	18,000	2,600	08/22/97
Total Xylenes	8240	29,000	2,600	08/22/97
Ethylbenzene	8240	4,100	2,600	08/22/97
C-range Compounds	Method	Percentage of Total	Detection Limit (Not Applicable)	Date Analyzed
≤C06	GC/FID	8.38	NA	09/10/97
C07	GC/FID	12.23	NA	09/10/97
C08	GC/FID	9.50	NA	09/10/97
C09	GC/FID	7.41	NA	09/10/97
C10	GC/FID	8.99	NA	09/10/97
C11	GC/FID	10.65	NA	09/10/97
C12	GC/FID	11.49	NA	09/10/97
C13	GC/FID	10.59	NA	09/10/97
C14	GC/FID	9.39	NA	09/10/97
C15	GC/FID	6.48	NA	09/10/97
C16	GC/FID	3.05	NA	09/10/97
C17	GC/FID	1.02	NA	09/10/97
C18	GC/FID	0.51	NA	09/10/97
C19 >	GC/FID	0.31	NA	09/10/97

Approved by: Walter Hinchman

Walter Hinchman, Jr.
Qaulity Assurance Officer

Date: 9/10/97

Battelle
Columbus Laboratories

CHAIN OF CUSTODY RECORD

Form No. 002

Proj. No.	Project Title
G462201-30D0601	Nellis AFB / Bioslurping

SAMPLERS: (Signature)

DATE	TIME	SAMPLE I.D.	BTEX	Boiling Point Range	C Range	Container No.	Number of Containers	Remarks
12 AUG 97	0900	NAFB-27-Fuel	✓	✓			1	
14 AUG 97	0930	NAFB-28-Fuel	✓	X			1	

Relinquished by: (Signature)	Date/Time	Received by: (Signature)	Relinquished by: (Signature)	Date/Time	Received by: (Signature)
[signature]	15 AUG 97 1115				
Relinquished by: (Signature)	Date/Time	Received by: (Signature)	Relinquished by: (Signature)	Date/Time	Received by: (Signature)
Relinquished by: (Signature)	Date/Time	Received for Laboratory by: (Signature)	Date/Time	Remarks	
	8/19/97 0800	[signature]		Results; Attn: Al Pollack FAX (614) 424-3667	

Alpha Analytical, Inc.
255 Glendale Avenue, Suite 21
Sparks, Nevada 89431
Phone (702) 355-1044
Fax (702) 355-0406

Billing Information:
Name
Address
City, State, Zip
Phone Number ? Fax

Client Name Battelle	P.O. #	Job # 7741201-301
Address	PWS #	DWR #
City, State, Zip	Phone #	Fax #

Sampled by Client
Report Attention

Analyses Required: BAE | Boiling Pt. Range | O Range

Time Sampled	Date Sampled	Matrix* See Key Below	Office Use Only Lab ID Number	Sample Description	Total and type of containers ** See below	BAE	Boiling Pt. Range	O Range						REMARKS
	8/12	OT	BMI970808-01	NAFB-27-Fuel	1	X	X							
	8/14	✓	02	NAFB-28-Fuel	1	X	X							

SPECIAL INSTRUCTIONS:
Fuel
COC broken
16°

	Signature	Print Name	Company	Date	Time
Relinquished by					
Received by	Linda Watson	Linda Watson	AAI	8/19/97	0800
Relinquished by	Dominic Ed...	Dominic Ed...	AAI	8/21/97	1150
Received by	Deane H	Deane H	Chemax	8/21/97	1150
Relinquished by					
Received by					

NOTE: Samples are discarded 60 days after results are reported unless other arrangements are made. Hazardous samples will be returned to client or disposed of at client expense.

*Key: AQ - Aqueous SO - Soil WA - Waste OT - Other **: L-Liter V-Voa S-Soil Jar O-Orbo T-Tedlar B-Brass P-Plastic OT-Other

APPENDIX C

SYSTEM CHECKLIST

Checklist for System Shakedown

Site:s 27 + 28

Date: 8 · 8 · 97

Operator's Initials: GH

Equipment	Check if OK	Comments
Liquid Ring Pump	✓	
Aqueous Effluent Transfer Pump	✓	
Oil/Water Separator	✓	
Vapor Flow Meter	✓	
Fuel Flow Meter	✓	
Water Flow Meter	✓	
Emergency Shut Off float Switch Effluent Transfer Tank	✓	
Analytical Field Instrumentation GasTechtor O_2/CO_2 Analyzer TraceTechtor Hydrocarbon Analyzer Oil/Water Interface Probe Magnehelic Boards Thermocouple Thermometer	 ✓ ✓ ✓ ✓ ✓	

APPENDIX D

DATA SHEETS FROM THE SHORT-TERM PILOT TESTS

Baildown Test Record Sheet

Site: Nellis AFB, Site 27

Well Identification: MW-24

Well Diameter (OD/ID): 2" PVC

Date at Start of Test: 8/9/97

Sampler's Initials: ____

Time at Start of Test: 11:33

Initial Readings

	Depth to Groundwater (ft)	Depth to LNAPL (ft)	LNAPL Thickness (ft)	Total Volume Bailed (L)
8/8/97	73.67	68.20	5.47	3.5L

Test Data

Sample Collection Time	Depth to Groundwater (ft)	Depth to LNAPL (ft)	LNAPL Thickness (ft)
8/9/97 1133	69.79	69.79	0.00
" 1208	70.43	69.74	0.69
" 1452	71.59	69.44	2.15
" 1723	72.20	69.25	2.95
8/10/97 0830	73.94	68.98	4.96
" 1110	73.97	68.95	5.02
" 1408	75.10	70.04	5.06
8/9/97 1148	70.18	69.80	0.38

Figure 9. Typical Baildown Test Record Sheet

Baildown Test Record Sheet

Site: Nellis AFB, Site 28

Well Identification: MW-31

Well Diameter (OD/ID): 2" PVC

Date at Start of Test: 8/9/97

Sampler's Initials: _____

Time at Start of Test: 10:00

Initial Readings

Depth to Groundwater (ft)	Depth to LNAPL (ft)	LNAPL Thickness (ft)	Total Volume Bailed (L)
67.89	60.89	7.00	16.5L

Test Data

Sample Collection Time	Depth to Groundwater (ft)	Depth to LNAPL (ft)	LNAPL Thickness (ft)
8/9/97 1022	63.32	62.73	0.59
" 1025	63.20	62.47	0.73
" 1037	63.12	62.31	0.81
" 1220	63.19	62.24	0.95
" 1430	63.17	62.19	0.98
8/10/97 1130	63.29	62.20	1.09
8/11/97 1600	63.24	62.15	1.09
8/12/97 1515	63.31	62.18	1.13

Figure 9. Typical Baildown Test Record Sheet

BATTELLE	SOIL GAS SURVEY INFORMATION	DATE: 8/15/97 1500
METERS (SERIAL NUMBERS): O_2 ____ CO_2 ____ TPH ____		SITE: Nellis AFB, Site 27

POINT #	DEPTH (ft. & tenths) (e.g., 10.2')	READINGS O_2 (%)	READINGS CO_2 (%)	READINGS TPH (ppm)	PUMP PRESS (in Hg. Vac.)	Recorded by: ____ Comments
MPA 55'	55'	0.0	0.5	>100,000		
65'	65'	0.0	25%	>100,000		
70'	70'	0.8	0.7	55,800		
MPB 55'	55'	0.0	2.8	46,600		
65'	65'	PLUGGED →				
70'	70'	0.0	0.7	>100,000		
MPC 55'	55'	0.0	0.7	>100,000		
65'	65'	PLUGGED →				
70'	70'	0.0	0.6	>100,000		

Record Sheet for In Situ Respiration Test

Site Nellis AFB, Site 27	Monitoring Point MPA-55
Shutdown Date 8/17/97	O_2/CO_2 Meter No. / TPH Meter No.
Shutdown Time 0940	Recorded by

Date	Time	O_2 (%)	CO_2 (%)	TPH (ppm)	He (%)	Temperature (°C)	Comments
8/17/97	0940	20.8	0.0	180	2.1		
"	1120	20.5	0.0	180	2.0		
"	1700	20.5	0.0	380	2.0		
8/18/97	1000	19.8	0.0	840	2.2		
"	1515	20.1	0.0	920	2.1		
8/19/97	0745	19.3	0.0	1280	2.0		
8/20/97	0930	19.0	0.0	1600	2.2		

Record Sheet for In Situ Respiration Test

Site Nellis AFB, Site 27

Monitoring Point MPB-70

Shutdown Date 8/17/97

O_2/CO_2 Meter No.

TPH Meter No.

Shutdown Time 0940

Recorded by

Date	Time	O_2 (%)	CO_2 (%)	TPH (ppm)	He (%)	Temperature (°C)	Comments
8/17/97	0940	20.4	0.0	300	2.0		
"	1120	19.8	0.0	500	2.1		
"	1700	18.5	0.0	1380	2.2		
8/18/97	1000	14.9	0.0	3600	2.0		
"	1515	14.6	0.0	4320	2.0		
8/19/97	0745	11.7	0.0	5840	2.5		
8/20/97	0930	9.3	0.0	7400	2.3		

Record Sheet for In Situ Respiration Test

Site Nellis AFB, Site 27

Shutdown Date 8/17/97

Shutdown Time 0940

Monitoring Point MPC-55

O_2/CO_2 Meter No.

TPH Meter No.

Recorded by

Date	Time	O_2 (%)	CO_2 (%)	TPH (ppm)	He (%)	Temperature (°C)	Comments
8/17/97	0940	20.4	0.0	220	1.8		
"	1120	20.4	0.0	340	2.0		
"	1700	20.0	0.0	680	1.6		
8/18/97	0950	18.9	0.4	1220	1.9		
"	1515	19.2	0.2	1600	1.5		
8/19/97	0745	18.4	0.4	1960	2.1		
8/20/97	0930	17.6	0.4	2540	1.9		

Fuel and Water Recovery

Site: Nellis AFB, Site 27
Well ID: MW-24
Test Type: Skimmer

Start Date: 8/10/97 16:00
End Date: 8/12/97 08:30
Operators:

Date/Time (mm/dd/yr hr:min)	Elapsed Time (hours)	LNAPL Recovery Collected (gal)	LNAPL Recovery Total (gal)	LNAPL Recovery Rate (gal)	LNAPL Recovery Avg. Rate (gph)	Groundwater Recovery Collected (gal)	Groundwater Recovery Total (gal)	Groundwater Recovery Rate (gal)	Groundwater Recovery Avg. Rate (gph)
8/10/97 16:00	0								
8/12/97 08:30	40.5	3 L (0.8 gal)	3 L (0.8 gal)						
		(1 L in tank & 2 L in ferret pump line)							

Total Time (hours) 40.5	Rate (gph) 0.020	Rate (gpd) 0.47	Rate (gph)	Rate (gpd)

Fuel and Water Recovery

Site: Nellis AFB, Site 27
Well ID: MW-24
Test Type: Bioslurper

Start Date: 8/12/97 11:00
End Date: 8/16/97
Operators:

Start
8/12/97 11:00

Date/Time (mm/dd/yr hr:min)	Elapsed Time (hours)	LNAPL Recovery Collected (gal)	LNAPL Recovery Total (gal)	LNAPL Recovery Rate (gal)	LNAPL Recovery Avg. Rate (gph)	Groundwater Recovery Collected (gal)	Groundwater Recovery Total (gal)	Groundwater Recovery Rate (gal)	Groundwater Recovery Avg. Rate (gph)
8/12/97 11:30	0.5							8l/88sec	
8/12/97 13:10	2.2							6l/68sec.	
8/12/97 18:10	7.1							6l/70sec.	
8/13/97 07:30	20.4						1608(+) 150	8l/87sec	
" 15:00	27.8						2209(+) 160		
8/14/97 08:20	44.9						3714(+) 160	8l/93sec	
" 14:00	50.5						4215		
8/15/97 09:45	70.1						5915	4l/49sec.	
8/16/97 08:30	92.7						7900(+) 170	6l/72sec	
" 11:00	95.2	1.5l	1.5l	(0.40gal)					
							8070		
Total Time (hours) 96		Rate (gph)		Rate (gpd)		Rate (gph)		Rate (gpd)	

Fuel and Water Recovery

Site: Nellis AFB, Site 27
Well ID: MW-24
Test Type: Drawdown

Start Date: 8/16/97 16:00
End Date: 8/18/97 09:45
Operators:

Date/Time (mm/dd/yr hr:min)	Elapsed Time (hours)	LNAPL Recovery Collected (gal)	LNAPL Recovery Total (gal)	LNAPL Recovery Rate (gal)	LNAPL Recovery Avg. Rate (gph)	Groundwater Recovery Collected (gal)	Groundwater Recovery Total (gal)	Groundwater Recovery H_2O meter (gal) ~~Rate (gal)~~	Groundwater Recovery Avg. Rate (gph)
8/16/97 16:00	0	0						8292	8l/96 sec
8/17/97 08:50	16.5	0						9696	
8/18/97 09:30	40.8	0						11627	8l/117 sec
" 09:45	41	0	0						
								3335 gal	= tot

Total Time (hours) 41	Rate (gph) 0	Rate (gpd)	Rate (gph)	Rate (gpd)

Fuel and Water Recovery

Site: Nellis AFB, Site 28
Well ID: MW-31
Test Type: Skimmer

Start Date: 8/12/97 1600
End Date: 8/14/97 0930
Operators:

Date/Time (mm/dd/yr hr:min)	Elapsed Time (hours)	LNAPL Recovery				Groundwater Recovery			
		Collected (gal)	Total (gal)	Rate (gal)	Avg. Rate (gph)	Collected (gal)	Total (gal)	Rate (gal)	Avg. Rate (gph)
8/12/97 1600	0								
8/13/97		~50ml							
8/14/97 0930	41.5	2.5 L	2.5L	(0.66gal)					
Total Time (hours) 41.5		Rate (gph)		Rate (gpd)		Rate (gph)		Rate (gpd)	

Fuel and Water Recovery

Site: Nellis AFB, Site 28
Well ID: MW-31
Test Type: Bioslurper

Start Date: 8/14/97 1130
End Date: 8/18/97 1050
Operators:

Date/Time (mm/dd/yr hr:min)	Elapsed Time (hours)	LNAPL Recovery Collected (gal)	LNAPL Recovery Total (gal)	LNAPL Recovery Rate (gal)	LNAPL Recovery Avg. Rate (gph)	Groundwater Recovery Collected (gal)	Groundwater Recovery Total (gal)	Groundwater Recovery Hour Meter (gal) ~~Rate (gal)~~	Groundwater Recovery Avg. Rate (gph)	
8/14/97 1130	0							0000		
" 1440	3.2					~85 gal				
8/15/97 0855	21.4							556 + 160		803 gpd
" 1100	23.5									
8/16/97 0920	45.8							1460	80/195 sec	732 gpd
8/17/97 1042	71.2							2429		916 gpd
8/18/97 0800	92.5							3212		
" 1050	95.3		0					3333		

Total Time (hours)	Rate (gph)	Rate (gpd)	Rate (gph)	Rate (gpd)
95.3	0			

Fuel and Water Recovery

Site: Nellis AFB, Site 28
Well ID: MW-31
Test Type: Drawdown

Start Date: 8/18/97 1115
End Date: 8/19/97 1300
Operators:

Date/Time (mm/dd/yr hr:min)	Elapsed Time (hours)	LNAPL Recovery Collected (gal)	LNAPL Recovery Total (gal)	LNAPL Recovery Rate (gal)	LNAPL Recovery Avg. Rate (gph)	Groundwater Recovery Collected (gal)	Groundwater Recovery Total (gal)	Groundwater Recovery Rate (gal)	Groundwater Recovery Avg. Rate (gph)
8/18/97 1115	0								
" 1445	3.5							3333	41/90 sec.
8/19/97 0830	21.25	0							
" 1300	25.75	0						4050.2	
								4224	
								891 gal	= total

Total Time (hours) 25.75	Rate (gph) 0	Rate (gpd)	Rate (gph)	Rate (gpd)

Bioslurping Pilot Test
(Data Sheet 2)
Pilot Test Pumping Data

Page ____ of ____

Site: Nellis AFB, Site 27

Start Date: 8/12/97

Operators: ____________

Start Time: 11:00

Test Type: Bioslurper

Well ID: MW-24

Depth to Groundwater: ________ Depth to Fuel: ________

Depth of Tube: 71.2'

Date/Time	Run Time	Vapor Extraction: Stack Pressure (in. H_2O)	Vapor Extraction: Hour Meter	Vapor Extraction: Flowrate (scfm)	Seal Water Temp. (°C)	Pump Head Vacuum (in. Hg)	Extraction Well Vacuum (in. H_2O)
8/12/97 11:00	0	0.005	316.3		94.2		48-50
" 11:30	0.5	0.005	316.8		102	25	53
" 13:10	2.2	0.005	318.5		102	24	53
" 18:10	7.1	0.005	323.4		102	24	50
8/13/97 07:30	20.4	0.005	336.7		98.4	-24	50
" 15:00	27.8	0.005	344.1		106	-24	47
8/14/97 8:20	44.9	0.005	361.2		99	24	50
14:00	50.5	0.005	366.8		107.4	24	50
8/15/97 9:45	70.1	0.008	386.4		100	24	51
8/16/97 8:30	92.7	0.005	409		102	24	50
8/16/97 11:00	95.2						

Figure 11. Typical Record Sheets for Bioslurper Pilot Testing (Continued)

Bioslurping Pilot Test
(Data Sheet 2)
Pilot Test Pumping Data

Page ____ of ____

Site: Nellis AFB, Site 27

Start Date: 8/16/97

Operators: ____________

Start Time: 16:00

Test Type: Drawdown

Well ID: MW-24

Depth to Groundwater: ________ Depth to Fuel: ________

Depth of Tube: 74.2'

Date/Time	Run Time	Vapor Extraction			Seal Water ~~Pump Stack~~ Temp (°C)	Pump Head Vacuum (in. Hg)	Extraction Well Vacuum (in. H_2O)
		Stack Pressure (in. H_2O)		Flowrate (scfm)			
8/16/97 16:00	0	0.01	415.2			23"	
8/17/97 8:50	16.5	0.012	431.7		103	23	
8/18/97 9:30	40.8	0.018	456.0		105	23	
" 9:45	41		456.2				

Figure 11. Typical Record Sheets for Bioslurper Pilot Testing (Continued)

Bioslurping Pilot Test
(Data Sheet 2)
Pilot Test Pumping Data

Page ___ of ___

Site: Nellis AFB, Site 28

Operators: ______

Test Type: Bioslurper

Depth to Groundwater: ______ Depth to Fuel: ______

Start Date: 8/14/97

Start Time: 1130

Well ID: MW31

Depth of Tube: 63.45

Date/Time	Run Time	Vapor Extraction: Stack Pressure (in. H_2O)	Vapor Extraction: Carbon Drums (in. H_2O)	Vapor Extraction: Flowrate (scfm)	Seal Water ~~Pump Stack~~ Temp (°C)	Pump Head Vacuum (in. Hg)	Extraction Well Vacuum (in. H_2O)
8/14/97 1130	0				111.2	21	47
" 1440	3.2				125	20	45
8/15/97 855	21.4	0.02			113	21	47
8/16/97 920	45.8	0.01			113	21	47
8/17/97 1042	71.2	0.01			116	-21	46
8/18/97 0800	92.5	0.01			110	-21	46.5
" 1050	95.3						

Figure 11. Typical Record Sheets for Bioslurper Pilot Testing (Continued)

Bioslurping Pilot Test
(Data Sheet 2)
Pilot Test Pumping Data

Page ____ of ____

Site: Nellis AFB, Site 28

Operators: ____________

Test Type: Drawdown

Depth to Groundwater: ________ Depth to Fuel: ________

Start Date: 8/18/97

Start Time: 1115

Well ID: MW-31

Depth of Tube: 66.45

Date/Time	Run Time	Vapor Extraction: Stack Pressure (in. H_2O)	Vapor Extraction: Carbon Drums (in. H_2O)	Vapor Extraction: Flowrate (scfm)	Seal Water ~~Pump Stack~~ Temp (°C)	Pump Head Vacuum (in. Hg)	Extraction Well Vacuum (in. H_2O)
8/18/97 1115	0	0.015				20	
1445	3.5				124.8	19.5	
8/19/97 830	21.25	0.015			111	20	
1300	25.75				125	20	

Figure 11. Typical Record Sheets for Bioslurper Pilot Testing (Continued)

APPENDIX E

IN SITU RESPIRATION TEST RESULTS

In Situ Respiration Test

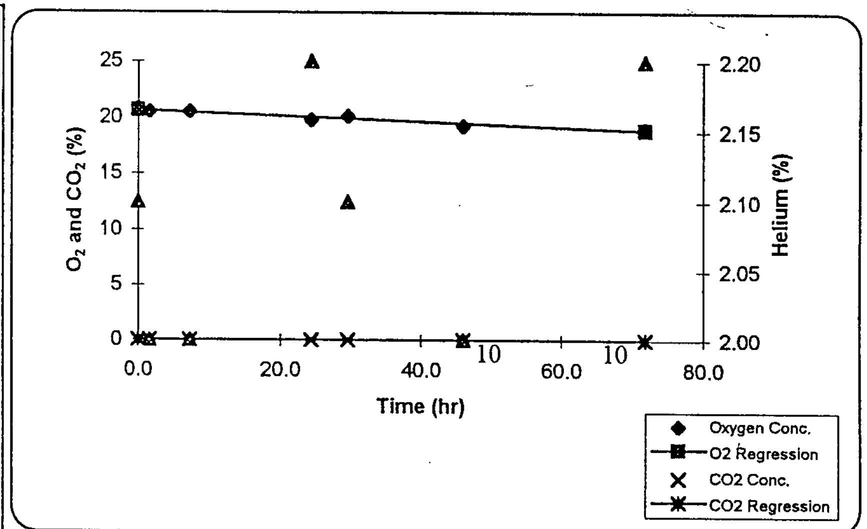
Date: 8/17/97

Site Name: Nellis AFB, NV

Monitoring Point: MPA

Depth of M.P. (ft): 55

Date/Time (mm/dd/yr hr:min)	Time (hr)	Oxygen (%)	Carbon Dioxide (%)	Helium (%)
8/17/97 9:40	0.0	20.80	0.00	2.10
8/17/97 11:20	1.7	20.50	0.00	2.00
8/17/97 17:00	7.3	20.50	0.00	2.00
8/18/97 10:00	24.3	19.80	0.00	2.20
8/18/97 15:15	29.6	20.10	0.00	2.10
8/19/97 7:45	46.1	19.30	0.00	2.00
8/20/97 9:30	71.8	19.00	0.00	2.20



O_2 Utilization Rate

Ko	0.000 %/min
	0.025 %/hr
	0.589 %/day

Regression Lines	O_2	CO_2
Slope	-0.0245	0.0000
Intercept	20.6340	0.0000
Determination Coef.	0.9294	1.0000
No. of Data Points.	7	7

In Situ Respiration Test

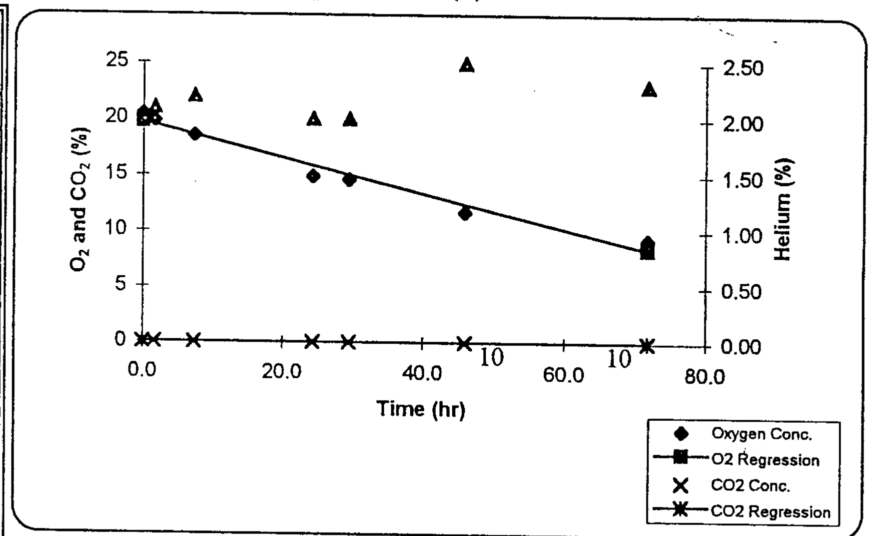
Date: 8/17/97

Monitoring Point: MPB

Site Name: Nellis AFB, NV

Depth of M.P. (ft): 70

Date/Time (mm/dd/yr hr:min)	Time (hr)	Oxygen (%)	Carbon Dioxide (%)	Helium (%)
8/17/97 9:40	0.0	20.40	0.00	2.00
8/17/97 11:20	1.7	19.80	0.00	2.10
8/17/97 17:00	7.3	18.50	0.00	2.20
8/18/97 10:00	24.3	14.90	0.00	2.00
8/18/97 15:15	29.6	14.60	0.00	2.00
8/19/97 7:45	46.1	11.70	0.00	2.50
8/20/97 9:30	71.8	9.30	0.00	2.30



O_2 Utilization Rate

Ko	0.003 %/min
	0.157 %/hr
	3.775 %/day

Regression Lines	O_2	CO_2
Slope	-0.1573	0.0000
Intercept	19.6638	0.0000
Determination Coef.	0.9703	1.0000
No. of Data Points.	7	7

In Situ Respiration Test

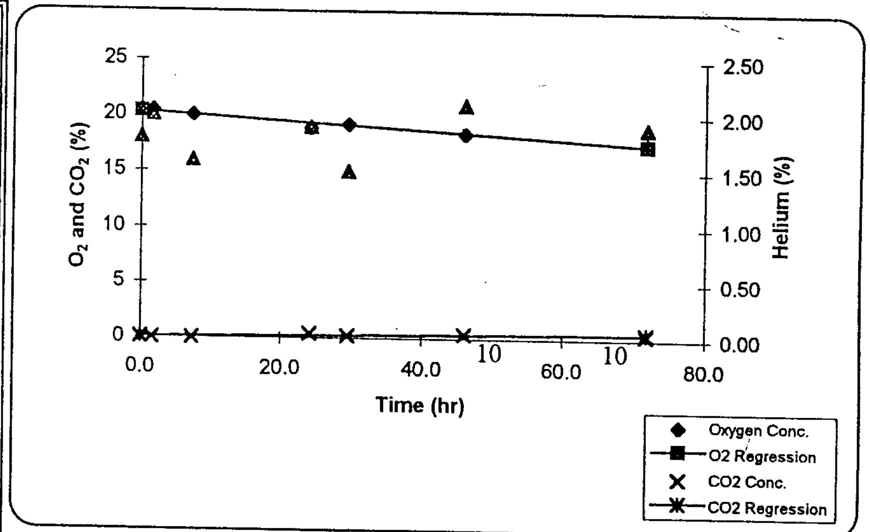
Date: 8/17/97

Site Name: Nellis AFB, NV

Monitoring Point: MPC

Depth of M.P. (ft): 55

Date/Time (mm/dd/yr hr:min)	Time (hr)	Oxygen (%)	Carbon Dioxide (%)	Helium (%)
8/17/97 9:40	0.0	20.40	0.00	1.80
8/17/97 11:20	1.7	20.40	0.00	2.00
8/17/97 17:00	7.3	20.00	0.00	1.60
8/18/97 9:50	24.2	18.90	0.40	1.90
8/18/97 15:15	29.6	19.20	0.20	1.50
8/19/97 7:45	46.1	18.40	0.40	2.10
8/20/97 9:30	71.8	17.60	0.40	1.90



O_2 Utilization Rate

Ko	0.001 %/min
	0.040 %/hr
	0.952 %/day

Regression Lines	O_2	CO_2
Slope	-0.0397	0.0064
Intercept	20.2952	0.0339
Determination Coef.	0.9608	0.7136
No. of Data Points.	7	7